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UPPER LLAGAS CREEK
FLOOD CONTROL PROJECT
MORGAN HILL, CALIFORNIA

SEDIMENT ASSESSEMENT AND
HYDRAULIC DESIGN
OFFICE REPORT

U.S. Army Engineer District, San Francisco
Corps of Engineers
San Francisco, California
December 2002

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TABLE OF CONTENTS

Section	Page
1.0 Introduction	1
1.0 Project Description	1
1.1 Project Authorization	1
1.2 Background	2
1.3 Approach and Data Sources	2
2.0 Hydrology Summary	4
3.0 Sediment Assessment	5
3.1 Geomorphic Conditions	5
3.2 Land Use History	6
3.3 Flow Duration Curves	7
3.4 Sediment Measurements	7
3.5 Suspended Sediment	8
3.6 Bed Material Sediment	8
3.7 Sedimentation Characteristics	8
3.8 Major Sediment Sources	10
3.9 Major Sediment Transport Mechanism	11
3.10 Sediment Yield Estimate	11
3.11 Sediment Assessment Conclusions and Recommendations	13
4.0 Hydraulic Analysis	
4.1 Computer Model	
4.1.1 Starting Water Surface Elevations	14
4.1.2 Manning's n-values	15
4.1.3 HEC-RAS Results	15
4.2 West Little Llagas Creek - Reaches 7 and 8	16
4.3 Reach 8 – West Little Llagas Creek, Downtown Morgan Hill	16
4.3.1 Reach 8 Alignment	16
4.3.2 Reach 8 Hydrology	17
4.3.3 Reach 8 Hydraulic Design	17
4.4 Reach 7 – Dunne Ave to Llagas Creek	21
4.4.1 Reach 7 Alignment	21
4.4.2 Reach 7 Hydrology	21
4.4.3 Reach 7 Hydraulic Design	22
4.4.4 Reach 7 Channel Stability	27

TABLE OF CONTENTS (Cont'd)

Section	Page
5.0 Llagas Creek Hydraulic Analysis - Reaches 4, 5 and 6	29
5.1 Reach 6 - Diversion Channel to 700 feet upstream Hwy 101	29
5.1.1 Reach 6 Alignment	30
5.1.2 Reach 6 Hydrology	30
5.1.3 Reach 6 Hydraulic Design	30
5.1.4 Reach 6 Channel Stability	33
5.2 Reach 5 – 700 feet Upstream Hwy 101 to East Little Llagas Creek	36
5.2.1 Reach 5 Alignment	36
5.2.2 Reach 5 Hydrology	36
5.2.3 Reach 5 Hydraulic Design	36
5.2.4 Reach 5 Channel Stability	37
5.3 Reach 4 - East Little Llagas Creek to Buena Vista Avenue	39
5.3.1 Reach 4 Alignment	39
5.3.2 Reach 4 Hydrology	39
5.3.3 Reach 4 Hydraulic Design	40
5.3.4 Reach 4 Channel Stability	41
6.0 East Little Llagas Creek– Reach 14	44
6.1.1 Reach 14 – Llagas Creek to 2400 feet upstream of San Martin Avenue	44
6.1.2 Reach 14 Alignment	44
6.1.3 Reach 14 Hydrology	44
6.1.4 Reach 14 Hydraulic Design	45
6.1.5 Reach 14 Channel Stability	48
7.0 Llagas Creek around Lake Silveira	50
8.0 References	52

LIST OF TABLES

Table No.	Subject	Page
1	Drainage Areas	4
2	Peak Flow Rates	5
3	Sediment Yield Calculation	12
4	West Little Llagas Creek – Reach 8 Design Flow Rates	17
5	West Little Llagas Creek – Reach 8 Culverts	18
6	West Little Llagas Creek – Reach 8 Channel Freeboard	20
7	West Little Llagas Creek – Reach 7 Design Flow Rates	22
8	West Little Llagas Creek – Reach 7a & b Culverts	24
9	West Little Llagas Creek – Reach 7a & b Levee Locations	25

LIST OF TABLES (cont'd)

Table No.	Subject	Page
10	West Little Llagas Creek – Reach 7b Levee Freeboard	26
11	West Little Llagas Creek Diversion – Reach 7a Freeboard	27
12	Llagas Creek – Reach 6 Design Flow Rates	30
13	Llagas Creek – Reach 6a Channel Freeboard	32
14	Llagas Creek – Reach 6 Existing Bridges	33
15	Llagas Creek – Reach 6 Streambank Protection	35
16	Llagas Creek – Reach 5 Design Flow Rates	36
17	Llagas Creek – Reach 5 Existing Bridges	37
18	Llagas Creek – Reach 5 Streambank Protection	39
19	Llagas Creek – Reach 4 Design Flow Rates	40
20	Llagas Creek – Reach 4 Existing Bridges	41
21	Llagas Creek – Reach 4 Streambank Protection	43
22	East Little Llagas Creek – Reach 14 Design Flow Rates	45
23	East Little Llagas Creek – Reach 14 Available Freeboard	47
24	East Little Llagas Creek – Reach 14 Existing Bridges	48
25	East Little Llagas Creek – Reach 14 Streambank Protection	49
26	Llagas Creek around Lake Silveria Levee Freeboard	51
27		

LIST OF PLATES

Plate No.	Subject
1	Llagas Creek Flood Control Project
2	Llagas Creek Study Watershed
3	Flow Duration Curve USGS gage 11153470
4	Flow Duration Curve USGS gage 11153555
5	Suspended Sediment at gage 11153470
6	Bed-Material Size Distribution gage 11153470
7	Bed-Material Size Distribution gage 11153530
8	Bed-Material Size Distribution gage 11153555
9	Bed-Material Size Distribution gage 11153500
10	Sediment Discharge Rating Curve gage 11153470
11	Reach 7 & 8 Water Surface Profiles
12	Reach 7 & 8 Channel Velocity Plot
13	Reach 8 Typical Section – Gabion
14	Reach 8 Typical Section – Santa Teresa Expwy Culvert
15	Reach 8 Typical Section – Above Hale Ave
16	Reach 7a Diversion Typical Section w/ levees
17	Reach 7a Diversion Typical Section w/ benches
18	Fish Barrier Schematic

LIST OF PLATES

Plate No.	Subject
19	Reach 7b Typical Section w/ 2-YR Discharge Channel
20	Reach 7b Typical Trapezoidal Section
21 a-b	Reach 7b Proposed Streambank Stabilization Features
22	Reaches 4 & 5 Mean HIS
23	Reach 6 Mean HSI
24	Reaches 4, 5 & 6 Mean HSI Summary
25	Reaches 5 & 6 Water Surface Profiles
26	Reaches 4, 5 & 6 Channel Velocities Plot
27	Reach 6a Set Back Levees Typical Section
28	Reach 6b & Reach 5 Typical Section w/ one bench
29	Reach 6b Typical Section w/ two benches
30	Reach 6b Typical Section downstream of San Martin Ave
31	Reach 4 Water Surface Profile
32	Reach 4 Typical Section
33	Reach 14 Water Surface Profile
34	Reach 14 Channel Velocity Plot
35	Reach 14 Typical Section
36	Llagas Creek around Silviera Lake Typical Section
37	Llagas Creek Water Surface Profile

APPENDICIES

Appendix A. Channel Design Summary Tables & Miscellaneous Calculations
Appendix B. Reaches 7 & 8 HEC-RAS Output and Cross-Sections
Appendix C. Reaches 4, 5 & 6 and around Silveira Lake HEC-RAS Output and Cross-Sections
Appendix D. Reach 14 HEC-RAS Output and Cross-Sections

UPPER LLAGAS CREEK
FLOOD CONTROL PROJECT
SEDIMENT ASSESSEMENT AND HYDRAULIC DESIGN REPORT

1. INTRODUCTION

The Upper Llagas Creek Flood Control Project (Project) is located in Southern Santa Clara County, California in the vicinity of the communities of Morgan Hill, San Martin and Gilroy. The project Sponsor, the Santa Clara Valley Water District (SCVWD), was successful in requesting Congress to transfer the projects authorization to the Corps of Engineers to complete the project in a timelier manner. In 1999, the District was authorized by congress to assume completion of the Llagas Creek Flood Control Project from the Natural Resources Conservation Service (NRCS). To date, the NRCS has completed about half of the originally authorized project.

1.1 PROJECT DESCRIPTION

Llagas Creek is a conduit to the Pajaro River and Monterey Bay encompassing a 90 square mile watershed and includes Chesbro Reservoir, a multipurpose facility for flood control and water supply. The Llagas Creek system, which includes Llagas Creek, West Little Llagas Creek and East Little Llagas Creek, is especially prone to flooding, having recorded floods in 1937, 1955, 1962, 1963, 1969, 1982, 1997 and 1998. The project objective consists of channel improvements and a diversion channel providing a 100-year level of protection to urban areas and between 5- to 10-year protection to agricultural areas.

The Llagas Creek Flood Control Project was separated into 14 reaches, as shown in **Plate 1**. The NRCS has completed about half of the originally authorized project, the lower portion below Buena Vista Avenue, consisting of Reaches 1, 2, 3, 9, 10, 11, 12 and 13. The current Upper Llagas Creek Flood Control Project (Project), which is addressed in this study, consists of the remaining reaches, located above Buena Vista Avenue, Reaches 4, 5, 6, 7, 8 and 14. The NRCS had developed preliminary designs for these reaches (Watershed Work Plan, 1967), however, changes in the environmental habitat within these reaches, overall watershed used and Federal and State laws necessitated a re-evaluation of these designs to prepare acceptable flood control features.

1.2 PROJECT AUTHORIZATION

The U.S. Department of Agriculture (USDA) under the Watershed Protection and Flood Prevention Act, Public Law 83-566 originally authorized the project in 1969. Since 1996, the construction of the upper reaches remained inactive due to lack of funding from the PL-566 program. The Water Resources and Development Act

(WRDA) of 1999 authorized the Corps of Engineers to complete the remaining reaches of the project, "substantially in accordance with the NRCS watershed plan".

1.3 BACKGROUND

The NRCS hydraulic design for the Upper Llagas Creek Project was complete in 1995. The design proposed various channel improvement work, including some widening of the existing channel and installation of seven (7) grade control structures and channel stability requirements as outlined in the watershed work plan.

Once the NRCS channel designs were completed a lack of available funding delayed the construction of the project. Additionally, the increased concerns over environmental impacts associated with the proposed NRCS project delayed project construction also. A field review in November 1999 indicated that the conditions in Reach 6 had dramatically changed since 1995, increasing the concern of the environmental impacts the NRCS design would have on the existing creek system.

The primary change was the natural establishment of very healthy dense vegetation in the channel due to re-operation of releases from Chesbro Reservoir. The near perennial low flow channel created by the re-operation of Chesbro Reservoir provide very favorable conditions for the establishment of vegetation within the channel.

The project was transferred to the District, to complete the remaining reaches of the project in accordance with the watershed plan while taking into consideration the establishment of vegetation in the creek. The project consists of updating the hydrology, removal of grade control structures, a diversion channel, levee's, set back levees, a meandering effective discharge channel, low flow fish barriers, and minimizing impacts to the channel to the extent possible, while providing a 100-yr level of protection to urban areas and between a 5- to 10- year level of protection to agricultural areas.

1.4 APPROACH AND DATA SOURCES

The approach used in this report is derived from the following Corps of Engineers engineering and design guidelines:

ERDC/CHL TR-01-2 Hydraulic Design of Stream Restoration Projects
September 2001

EM 1110-2-1601 Hydraulic Design of Flood Control Channels
1 July 1991

EM 1110-2-4000 15 Dec. 1989	Sedimentation Investigations of Rivers and Reservoirs Change 1 10/31/95
EM 1110-2-1418 31 Oct. 1994	Channel Stability Assessment for Flood Control Projects
EM 1110-2-1205 15 Nov. 1989	Environmental Engineering for Flood Control Channels

The following data are used in the development of this report:

a. Watershed Work Plan, Llagas Creek. 1967. NRCS.
b. Topographic survey: Llagas Creek Flood Control Project, Gilroy to Morgan Hill, Santa Clara County, California. Conducted by Bestor Engineers, Inc, 2001. Horizontal datum: California State Plane Coordinates, Zone 3, NAD83 (92). Vertical Datum:. NAVD(88).
c. Aerial photographs of Llagas Creek and vicinity, 1942.
d. Map and Construction Plan for Morgan Hill Plaza Box Culverts at West Little Llagas Creek, Reach 7B. Undated. Santa Clara Valley Water District. Project 5027. NGVD29
e. Map and Construction Plan for W. Middle Ave. Bridge at West Little Llagas Creek, Reach 7A. 1990. Santa Clara Valley Water District. Project 50273. NGVD29
f. Map and Construction Plan for Watsonville Rd Bridge at West Little Llagas Creek, Reach 7A. 1990. Santa Clara Valley Water District. Project 5027. NGVD29
g. Map and Construction Plan for Cosmo and Edes Box Culverts at West Little Llagas Creek, Reach 7B. 1990. Santa Clara Valley Water District. Project 5027. NGVD29
h. Map and Construction Plan for La Crosse Dr. Box Culverts at West Little Llagas Creek, Reach 7A. 1989. Santa Clara Valley Water District. Project 5027. NGVD29
i. Edmundson – Tennant Avenues Realignment Project, Channel Crossing. 1989. City of Morgan Hill Public Works Department.
j. Sediment data collected by U.S. Geological Survey, Stations USGS 11153470, USGS 11153500, USGS 11153530, and USGS 11153555, 1971-1986.
k. Soil and sediment samples collected by the U.S. Natural Resources Service (formerly the U. S. Soil Service), 1963-1964
l. Improvement Plan Tract No. 7152, Hillwood Lane. City of Morgan Hill. Undated. Drawing 81-84. NGVD 29.

2.0 HYDROLOGY SUMMARY

Llagas Creek drains a watershed that extends from the upper heights of Mount Loma Prieta in the Santa Cruz Mountains to the lower agricultural plains of south Santa Clara County. The watershed is approximately 15 miles long and 6 miles wide, and is bisected along its length by Highway 101. The total area of the Llagas Creek watershed upstream of the Pajaro River is approximately 104 square miles. The upper 19 square miles of the watershed are regulated by Chesbro Reservoir, which was built in 1955 as a multipurpose facility. The Reservoir impounds a maximum conservation pool of 7,500 acre-feet and a maximum pool of 8,086 acre-feet.

Llagas Creek flows in a southeasterly direction with tributaries flowing into it from the Santa Cruz Mountains to the west and the Diablo range to the east. While the northern part of Santa Clara County drains into San Francisco Bay, Llagas Creek drains into the environmentally sensitive and remote coast of Monterey Bay through the Pajaro River.

The Upper Llagas Creek Flood Control Project is covers a drainage area of 61.7 square miles and is located in the middle section of the watershed that extends from West Little Llagas Creek upstream of Wright Avenue, via the diversion channel to Buena Vista Avenue upstream of Panther Creek on Llagas Creek. The Project area is divided into three watersheds, the Llagas Creek watershed, which includes Chesbro Reservoir, the West Little Llagas Creek watershed, which includes the diversion channel and the East Little Llagas Creek watershed. The Project drainage areas are shown in Table 1. A map of the study watershed is shown in **Plate 2.**

Table 1
Upper Llagas Creek Drainage Areas

Location	Drainage Area (mi^2)
Llagas Ck at Chesbro Reservoir	19.2
Llagas Ck upstream West Little Llagas Ck	27.51
West Little Llagas Ck upstream Llagas Ck	5.73
Llagas Ck downstream West Little Llagas Ck	33.24
Llagas Ck upstream East Little Llagas Ck	35.50
East Little Llagas Ck upstream Llagas Ck	20.96
Llagas Ck downstream East Little Llagas Ck	56.46
Llagas Ck upstream Panther Ck	61.70

The hydrology developed for the NRCS study was revisited in 2002 to account for new data, potential urban growth and existing reservoir conditions. The results from the current study and used in the project design are shown in Table 2. Due to a longer period of record of rainfall data and better loss rate data, the flow rates have, in

general decreased, except in Reaches 7 and 8 where the peak flows increased slightly. The study indicates that the projected urbanization in the upper watershed will not significantly impact the already constructed portion of creek, below Buena Vista Avenue. This is due to the fact that the previous study overestimated precipitation.

For more complete information and analysis on the overall hydrology of the project area, refer to a separate hydrology report; Llagas Creek Flood Control Project Hydrologic Investigation, dated September 2002.

Table 2
Upper Llagas Creek Peak Flow Rates

Reach	Location	Area (sq.mi.)	50% Peak (cfs)	10% Peak (cfs)	1% Peak (cfs)	Design (cfs)
Llagas Creek						
	Chesbro Inflow (IS = 6000 ac-ft)	19.2	n/a	3,098	6,548	n/a
	Chesbro Outflow	19.2	n/a	494	3,916	n/a
6	u/s West Little Llagas (WLL) Diversion	27.51	430	1,925	4,858	4,900
6	d/s WLL Diversion	33.24	1,101	2,986	5,532	3,300
5	u/s East Little Llagas (ELL)	35.5	1,309	3,276	5,775	3,300
4	d/s ELL	56.47	n/a	6,720	11,523	3,300
4	u/s Rucker Ck	58.41	2,765	6,790	11,829	3,450
4	u/s Panther Ck	61.71	2,840	7,122	12,568	3,450
West Little Llagas Creek						
8	WLL u/s Wright Ave	1.53	186	398	636	650
7	WLL u/s Dewitt Ck (d/s Ciolino Ave)	2.61	344	717	1,129	1,100
7	WLL d/s Dewitt Ck (u/s Spring Ave)	3.37	454	944	1,483	1,500
7	WLL u/s Edmundson Ck (d/s N. La Crosse)	4.09	542	1,050	1,579	1,600
7	WLL Diversion u/s Llagas Ck	5.73	687	1,345	2,037	2,050
East Little Llagas Creek						
14	ELL u/s Corralitos Ck	6.58	2,298	1,563	2,155	1,600
14	ELL u/s San Martin Ck	14.54	4,450	2,535	4,051	2,550
14	ELL u/s Church Ck	18.96	5,666	3,149	5,136	3,150
14	ELL u/s Llagas Ck	20.97	6,413	3,444	5,780	3,450

3.0 SEDIMENT ASSESSMENT

3.1 Geomorphic Conditions

The Llagas Creek watershed is located in southwestern Santa Clara County, California. It is a tributary of the Pajaro River, which has a drainage area of 1, 273 square miles. Approximately 47 percent of the watershed is comprised of valley floor that is highly productive agricultural land. The valley area ranges in elevation from 140 to 400 feet above sea level. From the valley floor, steep hills rise to an elevation of 1,600 feet in the east and 3,560 feet in the west.

The geology of the watershed is typical of the Central Coast Range of California. Structurally, the watershed is divided into three sections, namely, the Santa Cruz Mountains in the upper portion, hilly section and the lower flat section. The San Andreas Fault passes through the foothills of watershed. The soils are generally classified as a silty loam of the Post-Aromas sediments. The Franciscan sedimentary and igneous rocks underlying the mountainous areas are traversed by many large faults that have shattered the adjacent rocks. The valley floor, composed of debris from these rocks, is largely coarse-grained material although some limited areas are of silt and clay of flood plain and lacustrine origin.

The watershed has a temperate climate of warm dry summers and mild winters. Mean annual temperature is 58 F, with a monthly variation between 66 F in July and 48 F in January. Extreme temperatures in nearby Gilroy have varied between a low of 20 F and a high of 116 F. The average frost-free period is 273 days.

Mean annual precipitation varies between 19 inches in the valley area near the mouth of Llagas Creek and 40 inches near the summit of Mount Chuai. About 76 percent of the mean annual rainfall occurs between December 1 and March 1, and 92 percent between November 1 and April 30. Snowfall is rare and has no measurable influence on flood runoff.

Flooding within the watershed is almost exclusively associated with cyclonic storms. These storms move in from the Pacific Ocean and generally exceed 12 hour's duration. Percentage of runoff for equal rainfall amounts is substantially higher from the valley areas than from the hills.

3.2 Land Use History

The major land use is agricultural. There is an increasing use by urban development. All the urban and a great majority of the highly developed agricultural land within the watershed are concentrated on the valley floor. The larger land holdings with a lower type of land use are found in the uplands. There is no federal land within the watershed.

Nearly one-half of the watershed population lives on 500 separate farm units, most of which are owner operated. About 50 percent of these farms are in the floodplain area.

The land is predominantly devoted to prune orchards with small areas in strawberries and other row crops, grains, and hay. Many walnut orchards are located along Llagas Creek below Chesbro Dam. Poultry and cattle grazing are quite extensive along the valley fringes.

Urban development is expected to continue at an accelerating pace even without flood protection. Studies by the Santa Clara County indicated that agriculture would remain the dominant land use for many years to come.

3.3 Flow Duration Curves

Based on flow data collected by USGS at Stations 11153470 and 11153555, a flow frequency analysis was conducted and the results are plotted as a flow duration curve as shown in Plates 2 and 3. These flow duration curves are used in conjunction with the sediment-rating curve in calculating the sediment yield, which is described in Section 3.4.

3.4 Sediment Measurements

Limited sediment data were collected by USGS at four water quality-sampling stations on Llagas Creek (Plate 4). All the four stations were discontinued. The following is a description of the stations.

- USGS Gage 11153470
  Hydrologic Unit Code 18060002
  Drainage area: 9.63 square miles

This gage was located on Llagas Creek above Chesbro Reservoir and is positioned at Latitude 37 Degree 08'54", Longitude 121 Degree 46'02". Flow discharge, water temperature, suspended and bed-load sediment data were collected during the period of December 24, 1971 and February 2, 1978. This gage is no longer in service.

- USGS Gage 11153500
  Hydrologic Unit Code 18060002
  Drainage area: 19.6 square miles

This gage was located on Llagas Creek downstream of Chesbro Reservoir near Morgan Hill and is positioned at Latitude 37 Degree 06'52', Longitude 121 Degree 41'22". Water quality and limited sediment data (bed-material sieve data only) were collected on February 10, 1985 and September 12, 1985. This gage is no longer in service.

- USGS Gage 11153530
  Hydrologic Unit Code 18060002
  Drainage area: 24.10 square miles

This gage was located on Llagas Creek at the Machado School near Morgan Hill and is positioned at Latitude 37 Degree 05'23', Longitude 121 Degree 39'38". Water

quality and limited sediment data (bed-material sieve data only) were collected on February 10, 1985, September 12, 1985, July 24, 1986, and August 12, 1987. This gage is no longer in service.

- USGS Gage 11153555
  Hydrologic Unit Code 18060002
  Drainage area: 28.20 square miles

This gage was located on Llagas Creek at San Martin and is positioned at Latitude 37 Degree 05'13', Longitude 121 Degree 36'15". Water quality and limited sediment data (bed-material sieve data only) were collected on February 10, 1985, September 12, 1985, and July 24, 1986. This gage is no longer in service.

3.5 Suspended Sediment

The size distribution of suspended sediment is presented in Plate 5. This is the only available field data collected by USGS at Gage 11153470. Plate 5 illustrates that the majority of the samples is 0.5 mm or finer. In the American Geophysical Union (AGU) Sediment Classification System, this range of sizes is characterized as fine sand (0.25 mm – 0.125 mm) and medium sand (0.5 – 0.25 mm).

3.6 Bed Material Sediment

Particle size distributions of bed-material collected at the four gaging stations are shown in Plates 6-9. Analysis of bed-material samples shows that sediment particle-sizes in the upstream section (Gage 11153470) tend to be larger relative to sediments in the downstream main stem of the Llagas Creek (Gage 11153555). The upstream section has sediment consists mostly fine to medium gravel (2 mm – 16 mm) and the downstream section has sediment consisting mostly fine gravel to fine sand (2 mm – 0.25 mm).

3.7 Sedimentation Characteristics

The Llagas Creek flows generally through coarse-grained fluvial material. The gravel fraction of this coarse-grained material is generally well rounded and for the most part consists of chert, metavolcanic, and greywacke fragments. The gravels are set in a matrix of silty or clayey sand and in some instances; the mass appears to be skip-graded, with the coarse sand sizes essentially not represented.

The sediment of Llagas Creek watershed can be divided into three types on the basis of origin: (1) residual soils, (2) those soils overlying older alluvium, and (3) the soils associated with the younger alluvium.

The residual soils found in the uplands have developed in place on, and are derived from the older rocks of the watershed. Those soils are shallow to moderate in depth and are underlain directly by bedrock, usually sandstone, shale or serpentine. Although the soils overlying the serpentine are generally heavy textured, medium texture predominates among the soils derived from the sedimentary rocks.

The soils formed on clear alluvial deposits are deep although several of the soils series in the category contain a clay pan. Medium texture predominates in these series, which occur as terraces, and high fan deposits along the margins of the Santa Clara Valley and its larger tributary stream valleys.

Soils of the center of the main valley have developed on the younger alluvium. This area is still subject to flooding, therefore many of the soils have no soil profile development. In texture the soils range from medium to coarse-grained. Prime agricultural land is closely associated with these soils.

The soils are alluvial channel and overbank sediments that have been deposited along Llagas Creek. A large proportion of gravel and sand with varying proportions of silt and clay characterizes most of the sediment.

The U.S. Natural Resource Conservation Service (References 1 to 3) has characterized the sediment by grouping them into four units. These four units are described below with differences based on their texture, densities, firmness and age.

Unit 1 – This unit is characterized by loose well-graded gravel with sand. It is found mostly on the surface and in the near surface of the existing channel bottom of Llagas Creek. The gravel ranges from 0.25 inches to 3.0 inches diameter and there is about one percent cobbles. There is from 35 to 45 percent well graded sand and almost no silt or clay fraction. It is recent alluvium deposited by high-energy flows. The material ranges from one to five feet thick.

Unit 2 – firm, dense, well-graded sand and gravels characterize this unit. Unified classification varies with the percents of gravel, sand and fines. It is found mostly at depths of 6 or more feet down from top of the bank or just below the recent alluvium in the channel bottom. Fines range from 5 to 10 percent, sands range from 30 to 55 percent and gravels range from 40 to 65 percent. Fines are very plastic indicating that they are probably mostly clay. It is old alluvium that has been buried by more recent deposits, compacted, and a small percent has weathered to silts and clays. Irregular lenses of sand or gravel can be found occasionally. This unit is the lower most and oldest unit sampled and it is not known how thick it is.

Unit 3 – This unit is characterized by moderately firm, somewhat dense, well-graded sand with gravels. It is found mostly in the stream banks, above the older alluvium and is often (Unit 2), but not always, buried by a loamy soil (Unit 4). It is similar to Unit 2 except for slightly less gravel and less clay and is less dense. Fines range from 1 to 5 percent, sands range from 50 to 60 percent and gravels range from

35 to 45 percent. Irregular lenses of clean sand or gravel are found randomly through this unit. This unit ranges in thickness from 6 to 11 feet and unit has been disturbed and mixed with trash in some places along the stream banks.

Unit 4 – This unit is characterized by loose to firm, silty sand. It is found on the surface at the top of the stream banks and adjacent ground. It consists of about 45 percent sand, 45 percent fines and 10 percent gravel. The clay ranges from 14 to 18 percent. It is recent overbank alluvium deposited during flooding events. This unit has been disturbed and mixed with trash in some places along the stream banks. The unit is generally 2 to 4 feet thick but ranges from 0 to 11 feet thick.

Much of the proposed Llagas Creek channel is earth channel with minimal excavation to occur. In an unlined channel Unit 1 and Unit 4 are susceptible to erosion. Unit 1 is susceptible to channel scouring and up to 5 feet degradation of the channel due to its location, loose nature and lack of fines. Unit 4 is susceptible to erosion because it is loose, but most of it occurs high enough in the channel banks that it is outside of the active channel and would be affected during high flows. Units 2 and 3 are good for channel embankments because they are well graded and dense. All of the units may contain small, irregular and discontinuous lenses of unstable material.

3.8 Major Sediment Sources

From the Watershed Work Plan, the major sediment sources are mostly in the watershed uplands where the slopes are steep for both the streambed and the streamside banks. Major erosion is generally confined to areas adjacent to stream channels, which are the only significant sediment sources.

Most of the major streams of the watershed are channeled through an inner gorge and the smaller tributaries debouch on the terrace above the stream where they drop what load they may be carrying and flow, unchannelized, across the relatively flat slope of the terrace. Thus, much of the sediment produced in the watershed does not reach the main streams but remains in the watershed as lag deposits.

Erosion in the upper watershed is not readily apparent under present good vegetation cover conditions. Shallow rills can be seen locally, but overall, sheet, rill and gully erosion are not apparent and the greatest source of sediment is from road cuts and associated ditches. Inasmuch as the upland soils are inherently erodible, an abrupt increase in the annual sedimentation rate would be expected to occur following an extensive burn in the watershed.

There has been some stream bank cutting. It is of minor extent and the proposed project improvement work will halt this source of sediment.

3.9 Major Sediment Transport Mechanism

The Chesbro Dam, completed in 1955, located at the headwater of the Llagas Creek, effectively functions as a sediment detention basin. The reservoir behind the Chesbro Dam has sediment storage of 110 acre-feet and 7,520 acre-feet of conservation storage.

A short distance upstream from the Highway 101 Bridge on Llagas Creek, a flattening of the stream gradient has caused the coarsest portion of the bed load in transport to be deposited. The downstream reaches, extending approximately to the Pacheco Pass Highway, contain a relatively shallow, finer gravelly bed load. This material is derived largely from limited erosion of the adjacent banks. Based on observations, this erosion is not excessive and the stream appears in near equilibrium with its bed load.

Downstream attrition of the gravels apparently reduces them to sizes capable of being carried as suspended load, as bed load of gravel size is uncommon in the lowest reaches of Llagas Creek.

The 19,000 feet reach of Llagas Creek between Highway 101 and Masten Avenue is the primary percolation area of the south Santa Clara Valley ground water basin.

The West Branch Llagas Creek and Miller Slough channels are in cohesive soils. There is no evidence of any appreciable erosion on either of these channels.

3.10 Sediment Yield Estimate

There is a lack of adequate measured sediment data to reliably and adequately estimate the sediment yield for the Llagas Creek. The only available sediment data that can be used in sediment yield estimate was from USGS Gage 11153470, located upstream of Chesbro Reservoir. Data on suspended sediment concentration and discharge were collected during the period from December 1971 to February 1978.

Based on the sediment data collected at USGS Gage 11153470, a sediment discharge-rating curve has been constructed and is shown in Plate 10. The sediment concentrations in milligrams per liter (MG/L) are converted to sediment discharge by using the following equation:

$$Qs = 0.0027 \times Qw \times C$$

Where

Qs = Sediment discharge, tons/day
0.0027 = Conversion constant from cfs to tons/day/1,000,000 parts
Qw = Mean daily water discharge, cubic feet per second (cfs)
C = Mean daily sediment concentration, MG/L or ppm

The Flow-Duration Sediment-Discharge Rating Curve Method (EM 1110-2-4000) is used to calculate the sediment yield. Flow duration curve based on flow data recorded at the same gaging station, USGS Gage 11153470, is integrated with the sediment-rating curve to produce the sediment yield estimate. The drainage area to USGS Gage 11153470 is 9.63 square miles. The calculation is shown in Table 3 and the total sediment yield is estimated at 1066 tons per day or 390,000 tons per year.

Table 3
Sediment Yield Calculation
Llagas Creek USGS Gage 11153470

Exceedence (%)	MidOrdinate (%)	Increment (%)	Flow Discharge (cfs)	Sediment Discharge (tons/day)	Daily Discharge (cfs)	Daily Sediment Discharge (tons/Day)
0						
	2.5	5	840	8000	42	400
5						
	7	4	770	6500	30.8	260
9						
	11	4	610	3500	24.4	140
13						
	15	4	540	2700	21.6	108
17						
	19	4	460	1080	18.4	43.2
21						
	23	4	380	980	15.2	39.2
25						
	30	10	270	450	27	45
35						
	40	10	175	150	17.5	15
45						
	50	10	140	60	14	6
55						
	60	10	120	50	12	5
65						
	70	10	90	28	9	2.8
75						
	80	10	70	15	7	1.5
85						
	90	10	40	3.3	4	0.3
95						
				Total	*242.9*	*1066*

This yield appears high as comparing to other similar watersheds. However, this yield should be viewed with the following considerations:

a. This data was collected at the upstream section of Llagas Creek where the sediment loading is usually higher,
b. This data was collected over only a six-year period with scattered intervals and many data missing. This means that the data could be highly skewed by one or two major storms, and
c. This data was collected above the Chesbro Reservoir and a major portion of the sediment will be trapped inside the reservoir.

3.11 Sediment Assessment Conclusions and Recommendations

Sediment enters the tributary streams and upstream section through rockslides and bank slumping. Generally, the downstream reaches of the Llagas Creek channel are relatively resistant to erosion because of the fine consolidated clay particles that make up the bed and bank material there. There have been some deposits of silt and fine sand dropped by overbank flow on agricultural lands during floods.

Although, sedimentation does not appear to be a major problem for the restored stream at Llagas Creek. Chesbro Reservoir, located at the upstream section of the creek, has effectively trapped the major sediment inflow to the project area. A more detailed and reach-specific sediment transport analysis, based on adequate field data and sediment transport modeling is recommended. Further reach-specific sediment analysis would provide estimates of sediment transport to predict channel conditions of the proposed design and identify problematic areas, which may exceed normal maintenance.

4.0 HYDRAULIC ANALYSIS

4.1 Computer Model

Water Surface profiles were computed using HEC-River Analysis System (HEC-RAS) program, developed by the U.S. Army Corps of Engineers. Cross Sections for input to the HEC-RAS model were taken at 100-ft intervals along the centerline, oriented left to right looking downstream. Additional cross sections were taken where needed to adequately model bridges and drops. An approximate centerline was laid out along each creek. The centerline along the channel does not follow the thalweg of the channel, however the invert shown on the flood profiles and cross sections does represent the thalweg of the channel. The stationing of the cross sections corresponds to the cumulative stream length, tying in with the Reach 3 of the completed downstream project.

It is important to note that all elevations in this report are based on the North American Vertical Datum of 1988 (NAVD88), as directed by EM 1110-1-1004 Deformation Monitoring and Control Surveying and that the NRCS study uses elevations in based on the National Geodetic Vertical Datum of 1929 (NGVD29). It was determined that in the area of Morgan Hill, to convert from NGVD29 to NAVD88, 2.8-ft should be added.

4.1.1 Starting Water Surface Elevations

Due to the updated hydrology the downstream boundary conditions used in the NRCS study could not be transferred directly to this study. Therefore, Llagas Creek was analyzed for subcritical flow conditions with a downstream normal depth boundary condition. The starting water surface elevations for all profiles was determined as the average slope of the channel near the downstream boundary in Reach 4. A normal depth slope of 0.0012 ft/ft was used in the analyses. This was based on the proposed channel design slope in Reach 4 and the "as-built" channel slope just downstream of Buena Vista Avenue, the downstream project boundary. The starting water surface elevations were compared with the "as-built" channel design slope in Reach 3, to get the average slope of the channel near the downstream project boundary.

The computed starting water surface elevations were verified by comparison to the stages determined by the NRCS. A discharge vs. stage curve was created from the NRCS hydraulic model and then using the updated discharge values a depth was derived for that value and compared to the depths determined by HEC-RAS. The results from HEC-RAS were determined to be equivalent to the downstream project conditions.

4.1.2 Manning's n-values

Manning's n-values were determined using procedures by Chow (1959) and in United States Geological Survey Water-Supply Paper 2339, Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains (1992). A base n-value for a straight, uniform smooth channel of a given material was selected and then adjusted according to the surface irregularity, variations in shape and size, obstructions, vegetation and meandering, and based on the available channel capacity. The channels in this study were earthen and gravel beds.

4.1.3 HEC-RAS Results

The HEC-RAS summary output files for the 2-year and design flow for the proposed design are included as part of the appendices of this report. Electronic input files are included on the CD presented separately. These files can be used to generated cross section plots and flood profiles.

Various supporting hydraulic design calculations and channel design summary tables are included in Appendix A. The proposed hydraulic design is summarized in the following sections.

draft

4.2 HYDRAULIC ANALYSIS FOR WEST LITTLE LLAGAS CREEK - REACHES 7 AND 8

The project along the West Little Llagas Creek, Reaches 7 and 8, consists of 3.85 miles of channel improvement work, to provide protection from the 100-year storm event. Channel width, throughout Reaches 7 and 8 is constrained by right-of-way limitations. The chosen alternative consists of channel enlargement and realignment, and levees to significantly increase the hydraulic capacity of West Little Llagas Creek.

4.3 Reach 8 – West Little Llagas Creek, Downtown Morgan Hill

Reach 8 is the most urbanized reach within the project limit. Reach 8 is located on West Little Llagas Creek in downtown Morgan Hill, between West Dunne Avenue to the project limits, approximately 800 feet upstream of Wright Avenue. Reach 8 is a highly urbanized creek area, with a seasonal occurrence of runoff, except in a few locations of perennial water due to urban runoff. Along the length of the creek in Reach 8 several homes or other buildings have been built next to the top of channel bank. The existing creek in Reach 8 consists of a trapezoidal earthen channel, with a top width of approximately 20 feet and an average depth of 4 feet. The existing channel capacity is approximately 300 cfs, less than the 10-year event. The creek passes through seven (7) culverts, all of which are undersized.

4.3.1 Reach 8 Alignment

West Little Llagas Creek, through Reach 8, is 1.15 miles in length. In general the existing channel alignment has been maintained, except in two locations where the channel will be relocated.

As part of the City of Morgan Hill's Master Plan, Hale Avenue will become an extension of the future Santa Teresa Expressway expansion and will be widened considerably. Between the upstream end of the project and Wright Avenue, the channel will be moved approximately 60 feet west of its present location to the existing SCVWD 100 ft right-of-way. The new alignment will tie into the existing channel at Hillwood Lane.

Between Del Monte Avenue and Warren Avenue, the existing creek is located very closely to two houses at Del Monte Avenue. The current property owner requested that creek be moved as far to the right (looking downstream) as possible, to avoid segmenting his properties.

4.3.2 Reach 8 Hydrology

The improvements to West Little Llagas Creek in Reach 8 are designed to provide protection from the 1% flood event or the 100-yr flood. The peak flows and design flows throughout Reach 8 are shown in Table 4. For comparison, the NRCS 1% & 10% flows are also included in Table 4. It can be seen from Table 4 that the peak flows in Reach 8 have increased slightly from the NRCS design peak flows.

Table 4
West Little Llagas Creek
Reach 8 Design Flow Rates

Location	Area (sq. mi)	50% Peak (cfs)		10% Peak (cfs)		1% Peak (cfs)	
		USACE	NRCS	USACE	NRCS	**USACE Design Q**	NRCS Design Q
Wright Ave.	1.53	185	-	400	400	**650**	620
Main Ave.	1.99	270	-	535	520	**840**	810
W. 5th Ave.	2.35	315	-	630	610	**990**	950
Ciolino Ave. (u/s Dewitt Ck)	2.61	350	-	700	690	**1100**	1050

4.3.3 Reach 8 Hydraulic Design

The design objective for this reach is to improve the aesthetic quality and amenity value of the creek within an urbanized watershed and increase the level of flood protection to provide protection from the 100-year flood. HEC-RAS was used to determine the water surface profiles for subcritical flow, the water surface profile for Reach 8 is shown on Plate 11.

Due to the urbanized nature of West Little Llagas Creek between West Dunne Avenue and Main Avenue and the limited available right-of-way, no maintenance access roads are included in the design. Channel maintenance access is along the channel bottom by lowering equipment into the channel. The proposed channel consists of 3092 feet (0.59 miles) of a trapezoidal vegetated gabion channel, with a geogrid low flow channel invert. The geogrid lining will allow for some vegetation, mostly grasses to grow along the invert of the channel, while providing a stable channel bottom for maintenance equipment. The proposed trapezoidal cross section has a 20-foot bottom width, 1V:0.5H side slopes and a varying depth of 7.5 to 10-feet and a maximum top width of 30 feet. The design assumes a Manning n-value of 0.04. The average channel velocities in this section of Reach 8 are 5.4 feet per second. A plot of Reach 8 velocities is shown on Plate 12. The effective discharge channel was not included in this section of Reach 8 due to lack of available right-of-way. A typical section is shown on Plate 13.

In contrast to the proposed design between West Dunne and Main Avenue, the NRCS design, through downtown Morgan Hill, a 14-foot wide concrete rectangular channel, minimized excavation and the necessary right-of-way, by designing the channel to flow under supercritical conditions.

Between W. Dunne and Main Avenue, there are five creek crossings at; W. Fifth, W. Fourth, W. Third, Del Monte Avenue and Warren Avenue. The existing culverts are undersized and are not capable of conveying the 1% flood event. Therefore, all the culverts need to be replaced. The existing culvert and design culvert information are included in Table 5.

Table 5
Reach 8 - West Little Llagas Creek
Proposed and Existing Culverts

Reach 8 Location	Proposed Design			Existing		
	Roadway Width (ft)	Culvert Size # - w(ft) x h(ft)	Type of X-ing	Roadway Width (ft)	Culvert Size w (ft) x h (ft)	Type of X-ing
5th Street	60	2 – 10 x 9	RCB	60	5 x 5	RCB
4th Street/ Monterey Hwy	270	2 – 10 x 9	RCB	270	9 x 6	RCB
3rd Street	14	2 – 10 x 9	RCB	14	14 x 7	RCB
2nd Street/ Del Monte Avenue	250	2 – 10 x 9	RCB	250	10 x 5	RCB
Warren Avenue	40	2 – 10 x 9	RCB	40	10 x 5	RCB
Main to Wright along Hale Ave (Future Santa Teresa Expwy)	2200	2 – 10 x 8	RCB	N/a	-	-
Main Street	N/a	-	-	70	9 x 5	RCB
Wright/Hale Avenue	N/a	-	-	110	60"	RCP

As part of the future Santa Teresa Expressway expansion between Main Avenue and Wright Avenue, the existing creek would be replaced with two (2) – 10-ft wide x 7-ft to 8-ft high reinforced concrete box (RCB) culverts under the expressway. A Manning n-value of 0.015 was assumed in this section of Reach 8. The total length of the RCB will be approximately 2200 ft (0.42 miles) and will follow the existing alignment on the left side of Hale Avenue, looking downstream. The culvert is designed to flow under open channel, subcritical conditions with maximum and

minimum velocities of 9.8 and 5.4 feet per second, respectively, with an average velocity of 7.6 feet per second. A typical section is shown on Plate 14.

The Santa Teresa Expressway expansion also affects the most upstream section of Reach 8, between Wright Avenue and the end of project, downstream of Hillwood Lane. The existing channel will be moved approximately 60 feet west of its present location to the existing SCVWD right-of-way. The proposed channel consists of approximately 600 feet (0.11 miles) of a trapizoidal channel. The proposed cross section consists of a trapizoid channel, with a 20-foot bottom width, 1V:3H side slopes and a depth of 8-feet and a top width of 70 feet. The design assumes a Manning n-value of 0.07. The average channel velocities in this section of Reach 8 are 2.8 feet per second. Maintenance access would be along the top of bank. The new alignment will tie into the ultimate design channel invert at Hillwood Lane. Hillwood Lane consists of an arched bridge, with an ultimate design invert of 344.78 ft (NAVD 88). The existing invert at Hillwood Avenue is 349.38. A typical section is shown on Plate 15.

The SVCWD freeboard requirements, Policy 3-218, dated September 16, 1995, requires that where the design water surface elevation is below natural ground, a minimum of one foot of freeboard or two-tenths of the total energy, which ever is greater, shall be used as the minimum freeboard requirement. The minimum freeboard necessary for Reach 8 varies from 1.0 – 1.8 feet. West Little Llagas Creek in Reach 8 has that capacity to carry the 1% design flow, however, Reach 8 does not have the ability to convey the channel capacity plus freeboard in several locations. Therefore, floodwalls will be necessary at several locations in Reach 8 to provide the required amount of freeboard. The freeboard requirements for Reach 8 are shown in Table 6.

The channel design summary table and various calculations for the proposed design are included in Appendix A. The HEC-RAS summary output and cross-section plots for West Little Llagas Creek are included in Appendix B.

0.59
0.42
0.11
1.12 miles

Table 6
Reach 8 – West Little Llagas Creek
Levee Freeboard

River Sta	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	0.2EG Freeboard (ft)	Levee El Left (ft)	Levee El Right (ft)	L. Levee Frbrd (ft)	R. Levee Frbrd (ft)	L. Freeboard (ft)	R. Freeboard (ft)
17550	337.73	345.86	346.26	**1.706**	347.6	347.6	*1.74*	*1.74*	1.65	1.64
17500	337.61	345.72	346.12	**1.702**	347.4	347.4	*1.68*	*1.68*	1.28	1.28
17400	337.37	345.52	345.91	**1.708**	347.2	347.2	*1.68*	*1.68*	1.48	1.48
17300	337.13	345.32	345.71	**1.716**	347	347	*1.68*	*1.68*	0.68	0.68
17225	336.95	345.12	345.51	**1.712**	346.8	346.8	*1.68*	*1.68*	0.88	0.88
17200	336.89	345.05	345.45	**1.712**	346.8	346.8	*1.75*	*1.75*	0.95	0.95
17100	336.65	344.86	345.25	**1.72**	346.8	346.8	*1.94*	*1.94*	1.14	1.19
17053.04	336.52	344.53	345.13	**1.722**	346.3		*1.77*		0.84	2.22
16935	336.19	344.09	344.51	**1.664**	345.8		*1.71*		0.92	2.23
16885	336.05	343.98	344.4	**1.67**	345.8		*1.82*		1.02	1.02
16800	335.74	343.74	344.15	**1.682**	345.7		*1.96*		1.26	1.84
16742.22	335.58	343.39	344.01	**1.686**	345.4		*2.01*		1.66	2.67
16487.74	334.87	342.92	343.51	**1.728**	345.1		*2.18*		1.35	1.9
16400	334.64	342.86	343.25	**1.722**	344.6	344.6	*1.74*	*1.74*	1.17	1.7
16300	334.36	342.68	343.06	**1.74**	344.4	344.4	*1.72*	*1.72*	-0.4	1.33
16200	334.08	342.5	342.87	**1.758**	344.3	344.3	*1.8*	*1.8*	-0.3	1.74
16109.16	333.83	342.15	342.7	**1.774**	344.27		*2.12*		2.12	1.9
16095.38	333.79	341.79	342.36	**1.714**	344.31		*2.52*		2.52	2.23
16000	333.52	341.7	342.09	**1.714**	343.4		*1.7*		0.11	3.46
15900	333.24	341.52	341.9	**1.732**	343.3		*1.78*		1.53	2.94
15800	332.96	341.33	341.7	**1.748**	343.1	343.1	*1.77*	*1.77*	1.51	1.19
15400	332.19	340.47	340.85	**1.732**		342.2		*1.73*	2.25	1.63
15300	331.96	340.13	340.61	**1.73**	341.9		*1.77*		1.18	1.89
15263.3	331.89	339.74	340.5	**1.722**	342.23		*2.49*		2.49	2.43
15199.41	331.76	339.14	340	**1.648**		342.09		*2.95*	2.78	2.84
15100	331.63	338.94	339.57	**1.588**		340.5		*1.56*	3.34	1.41

4.4 REACH 7 – Dunne Ave to Llagas Creek

West Little Llagas Creek, Reach 7 is located in an urban area of the city of Morgan Hill. Channel width, throughout Reaches 7 is constrained by right-of-way limitations and the available right-of-way varies between 115 and 180 feet. Reach 7 is also, located in a highly urbanized creek area, with a seasonal occurrence of runoff, except in a few locations of perennial water due to urban runoff along the existing section of West Little Llagas Creek. Reach 7 is subdivided into two Reaches, Reach 7a and 7b. Reach 7a, is located between La Crosse Street to the main branch Llagas Creek, via a diversion channel. The diversion channel consists of new earth channel construction, bypassing East Little Llagas Creek, redirecting West Little Llagas Creek, to flow directly into the main branch Llagas Creek at Silveira Lake. The Diversion Channel begins approximately 950 feet downstream of the southern Las Crosse Avenue Bridge Crossing, were the existing West Little Llagas Creek makes an abrupt turn east towards East Little Llagas Creek. Reach 7b is located between West Dunne Avenue and La Crosse Street.

4.4.1 Reach 7 Alignment

West Little Llagas Creek, Reach 7 is a total of 2.7 miles in length. The total length of Reach 7a is 1.3 miles. The existing West Little Llagas Creek channel alignment has been maintained for Reach 7a, except along the new diversion channel.

West Little Llagas Creek, through Reach 7b, is 1.4 miles in length. In general the existing channel alignment has been maintained, except near Cosmo Avenue. Approximately 200 feet downstream and 900 feet upstream of Cosmo Avenue, the existing channel will be abandoned and a new channel will be constructed approximately 100 feet to the west to keep the channel within the SCVWD right-of-way.

4.4.2 Reach 7 Hydrology

The improvements to West Little Llagas Creek in Reach 7 are designed to provide protection from the 1% flood event or the 100-yr flood. The peak flows and design flow rates throughout Reach 7 are shown in Table 7. For comparison, the NRCS 1% & 10% flows are also included in Table 7.

Table 7
West Little Llagas Creek
Reach 7 Design Flow Rates

Location	Drainage Area (sq. mi)	50% Peak (cfs)		10% Peak (cfs)		1% Peak (cfs)	
		USACE	NRCS	USACE	NRCS	**USACE Design Q**	NRCS Design Q
Downstream Ciolino Ave (Upstream Dewitt Ck)	2.61	350	-	700	690	**1100**	1050
Downstream Dewitt Ck	3.37	454	-	944	887	**1500**	1400
Upstream Edmundson Ck	4.09	542	-	1050	1071	**1600**	1650
Upstream Llagas Ck	5.73	687	-	1345	1451	**2050**	2200

4.4.3 Reach 7 Hydraulic Design

The design objective for Reach 7 is to provide 100-year level of protection and a stable channel, within the existing SCVWD right-of-way. Other design considerations were, the removal of the maintenance roads within the channel from the NRCS design, the addition of a fish barrier to preclude the steelhead from straying into West Little Llagas Creek during low flows, improved habitat for resident species, the addition of a effective discharge channel (where possible) and creek side trails. The 2-year recurrence interval was used to determine the effective discharge in the design of the effective discharge channel. Again, channel width, throughout Reaches 7 is constrained by right-of-way limitations. HEC-RAS was used to determine the water surface profiles for subcritical flow, the water surface profile for Reach 7 is shown on Plate 11.

Reach 7a, consists of 1.0 miles of new earth channel construction to create the diversion channel, connecting West Little Llagas Creek to the main branch Llagas Creek and 0.4 miles of widening and deepening of existing channel. The diversion channel connects with Llagas Creek, near Silveira Lake, approximately 2550 feet upstream of Monterey Hwy on Llagas Creek.

From the confluence to the downstream face of Middle Avenue the diversion channel proposed trapezoidal cross section has a 30-ft bottom width, 1V:2H side slopes and a 12-ft depth, with levees on both banks. The levee height varies from 5-ft to 6-ft, with 1V:2H side slopes and a top width of 12-ft. A maintenance access road and a creek side trail are to be located on top of the levees. A composite Manning n-value of 0.045 was assumed for the levee portion of the diversion channel. Upstream of Middle Avenue to the end of the diversion channel, at Station 59+00, and continuing to the downstream face of the southern La Crosse Street bridge, the proposed channel consists of approximately 2700 feet (1.05 miles) of a restored more natural channel, with a 2-year effective discharge channel. The proposed cross section consists of a two stage flood control channel, the 2-year effective discharge

channel has a 30-foot bottom width, 1V:2.5H side slopes and a depth of 6-feet, where it then transitions to high flow area of the channel, with 8-foot wide benches on the left and right side of the channel, 1V:2.5H side slopes and a top width of 120 feet. The design equivalent of a Manning n-value of 0.051 was determined. The average channel velocities in this section of Reach 7a are 4.0 feet per second. Maintenance access would be along the top of bank. Typical sections are shown on Plates 16 and 17.

A 2- ft high vertical V-notch concrete drop structure, will be located in the diversion channel 300-ft upstream from the confluence, at Station 14+00. The drop structure will help to prevent fish from straying into West Little Llagas Creek during low flows and the V-notch will allow out migration of errant fish that are able to migrate up West Little Llagas Creek . To create an undesirable condition for migrating steelhead, a concrete apron is to be placed upstream and downstream of the vertical drop, to prevent the erosion of the channel upstream of the drop and to prevent the creation of a pool below the drop. A schematic of the fish barrier in Reach 7a is shown on Plate 18.

Reach 7b consists of channel enlargement and realignment from the southern La Crosse Street to Ciolino Avenue. The proposed channel consists of approximately 7392 feet (1.4 miles) new channel to create a restored more natural channel. The proposed design in Reach 7a consists of two basic channel configurations, a trapezoidal channel and a two stage flood control channel.

Between the northern and southern La Crosse bridges, at the Edmundson Creek confluence, the proposed cross section consists of a two-stage flood control channel with a bench on the left, the 2-year effective discharge channel has a 30 to 50-foot bottom width, 1V:3H side slopes and a depth of 5-feet, where it then transitions to high flow area of the channel, with a 10 to 20-foot wide bench on the left side of the channel, 1V:3H side slopes and a top width of 110 to 145 feet. The design assumes a Manning n-value of 0.045 within the effective discharge channel and a Manning n-value of 0.06 within the high-flow section of channel. It was determined to be equivalent to a composite Manning n-value of 0.052. The average channel velocities in this section of Reach 7b are approximately 3 feet per second. Between northern La Crosse and Ciolino Avenue, the proposed design migrates between a trapezoidal channel and two-stage flood control channel with left and right benches. The channel configuration throughout this section of Reaches 7a is purely dependent on the right-of-way limitation. The proposed trapezoidal cross section has a 25-ft bottom width, 1V:2.5H side slopes and a 9 to 13-ft depth. The design of the trapezoidal cross section assumes a Manning n-value of 0.045.

The configuration of the two stage flood control channel has left and right benches, the 2-year channel-forming discharge channel has a 25-foot bottom width, 1V:3H side slopes and a depth of 4.5 to 5-feet, where it then transitions to high flow area of the channel, with a 8 to 10-foot wide benches, 1V:3H side slopes and a top width of 130 feet. The design assumes a Manning n-value of 0.045 within the

channel-forming discharge channel and a Manning n-value of 0.06 within the high-flow section of channel. It was determined to be equivalent to a composite Manning n-value of 0.052. The average channel velocities in this section of Reach 7b are 4.0 feet per second. Maintenance access would be along the top of bank. Typical sections are shown on Plates 19 and 20.

Between the confluence with the main branch Llagas Creek and W. Dunne, there are ten crossings over West Little Llagas Creek. Within Reach 7a, Middle Avenue and Watsonville Road would cross the Diversion channel. Both of these bridges have already been built by the SCVWD, based on the NRCS design and buried in place. Within Reach 7b, the creek crossings consists of 6 culverts and one bridge crossing. The existing culverts were built to the NRCS design and are capable of conveying the 1% flood event, except for a driveway bridge between Edes Court and Cosmo Avenue. The existing and proposed culvert and bridge data are included in Table 8.

Table 8
Reach 7 - West Little Llagas Creek
Existing and Proposed Channel Crossings

Reach 7 Location	Type of X-ing	Roadway Width (ft)	Existing Culverts		Existing Bridges	
			Culvert Size w (ft) x h (ft)	Number of Culverts	Pier Size (ft)	Number of Piers
Existing						
Middle Ave	Bridge	37	-	-	0.5	2
Watsonville Rd	Bridge	75	-	-	0.5	2
S. La Crosse	RCB	77	13 x 8	3	-	-
			12 x 11	1	-	-
N. La Crosse	RCB	94	16.5 x 9	2	-	-
			16.5 x 12	1	-	-
Edmundson Ave	RCB	92	12 x 10	3	-	-
Edes Ct	RCB	49	10 x 9	1	-	-
			10 x 7	2	-	-
Cosmo Ave	RCB	65	10 x 9	1	-	-
			10 x 7	2	-	-
Ciolino/Dunne	RCB	674	15 x 8	1	-	-
Proposed						
Driveway	Bridge	11.5	-	-	-	None
Spring Ave	RCB	60	10 x 9	3	-	-
Ciolino/Dunne addition	RCB	674	8 x 8	1	-	-

For Reach 7a, from the confluence with the main branch Llagas Creek to Middle Avenue, along the diversion channel the design water surface elevation is above

natural ground for the first 2300 feet of channel. According to the SVCWD freeboard requirements, Policy 3-218, the levee requirement specifies that a minimum of 3.5 feet in freeboard be used in this section of the diversion. From Middle Avenue, downstream 567 feet, the design water surface elevation is below natural ground, therefore a minimum of one foot of freeboard or two-tenths of the total energy, which ever is greater shall be used as the minimum freeboard requirement.

The proposed design in Reach 7b has that capacity to carry the 1% design flow, however, in a few locations Reach 7b does not have the ability to convey the channel capacity plus freeboard. Therefore, levees or floodwalls will be necessary to provide the required amount of freeboard. The minimum freeboard necessary for Reach 7b varies from 1.0 – 1.8 feet, based on a minimum of one foot of freeboard or two-tenths of the total energy, which ever is greater, as stated in SVCWD freeboard requirements, Policy 3-218.

The NRCS design required a total 4100 feet of levee, with a freeboard at least 3 feet above the design water surface elevation. The proposed design requires 5764 feet of levee in Reach 7a and 2606 feet of levee in Reach 7b. The greatest change in additional levee is within Reach 7b, the diversion channel. This is due the change in design in Reach 6 above Monterey Hwy, to set back levees and the need for 3.5 feet of freeboard instead of 3.0 feet as required in the NRCS design. The required levee within Reach 7b has been reduced slightly from the NRCS design. The current levee locations for Reach 7 compared to the NRCS design are included in Table 9 and the proposed freeboard for Reach 7 are shown in Table 10 and 11.

Table 9
West Little Llagas Creek - Reach 7 Levee Locations

Proposed Design			**NRCS Design**		
Station	**Left Bank (ft)**	**Right Bank (ft)**	**Station**	**Left Bank (ft)**	**Right Bank (ft)**
Reach 7a			**Reach 7a**		
12+00 - 30+66.74	1967	1867	10+00 - 12+00	200	200
64+00 – 66+00	-	200	29+00 - 31+00	200	200
66+00 – 71+00	500	500	*Total Levee R7a*	*400*	*400*
74+00 – 77+00	300	300	**Reach 7b**		
Total Levee R7a	*2767*	*2967*	90+00 - 94+00	400	-
Reach 7b			97+00 - 104+00	700	-
101+00 – 106+00	-	500	106+00 – 111+00	-	500
107+56.26-117+00	944	-	112+00 – 115+00	-	300
112+00 – 114+61.68	-	262	118+00 – 123+00	500	-
121+00 – 124+00	300	300	123+00 – 127+00	-	400
124+00 – 127+00	300	-	*Total Levee R7b*	*1600*	*1200*
Total Levee R7b	*1544*	*1062*			
Total Levee	*4311*	*4029*	*Total Levee*	*2000*	*1600*

The channel design summary table and various calculations for the proposed design are included in Appendix A. The HEC-RAS summary output and cross-section plots for Reach 7 are included Appendix C.

Table 10
Reach 7b – West Little Llagas Creek
Levee Freeboard

River Sta	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	0.2EG Freeboard (ft)	Levee El Left (ft)	Levee El Right (ft)	*L. Levee Frbrd (ft)*	*R. Levee Frbrd (ft)*	L. Freeboard (ft)	R. Freeboard (ft)
12600	324.14	332.09	332.25	1.622	334.07		*1.98*		1.08	4.03
12500	323.81	331.95	332.1	1.658	334.04		*2.09*		0.79	3.46
12400	323.48	331.83	331.96	1.696	333.97		*2.14*		0.58	3.56
12300	323.15	331.72	331.84	1.738	333.73	333.78	*2.01*	*2.06*	0.73	1.06
12200	322.82	331.62	331.74	1.784	333.95	333.89	*2.33*	*2.27*	0.39	1.16
12100	322.47	331.52	331.63	1.832	333.78	333.95	*2.26*	*2.43*	0.27	1.01
12050	322.3	331.52	331.59	1.858	333.95	334.05	*2.43*	*2.53*	0.8	1.94
11600	321.47	329.7	329.86	1.678	331.61		*1.91*		1.3	3.33
11473.77	321.22	329.53	329.68	1.692	331.222	331.372			1.68	1.45
11461.68	321.19	329.48	329.63	1.688	331.84	331.84	*2.36*	*2.36*	1.36	1.41
11400	321.07	329.39	329.55	1.696	331.38	331.38	*1.99*	*1.99*	1.01	0.62
11300	320.87	329.27	329.42	1.71	331.26	331.26	*1.99*	*1.99*	1.53	-0.03
11200	320.67	329.15	329.29	1.724	331.13				1.25	2.94
11100	320.47	329.03	329.17	1.74	331.01				0.73	2.04
11000	320.27	328.92	329.06	1.758	331.01				0.41	3.2
10900	320.07	328.81	328.94	1.774	330.79		*1.98*		0.11	1.23
10825.18	319.95	328.64	328.83	1.776	330.62	330.62	*1.98*	*1.98*	1.31	1.38
10785.24	319.83	328.27	328.77	1.788	329.42	329.3	*1.15*	*1.03*	1.15	1.03
10500	318.91	326.86	327.14	1.646		328.83		*1.97*	3.09	1.18
10400	318.63	326.7	326.97	1.668		328.67		*1.97*	2.7	0.73
10300	318.35	326.56	326.81	1.692		328.51		*1.95*	2.35	0.51
10200	318.07	326.42	326.66	1.718		328.36		*1.94*	1.73	0.72
10100	317.79	326.29	326.52	1.746		328.8		*2.51*	2.7	0.5
10000	317.51	326.18	326.39	1.776					1.73	1.86
7600	313.61	322.74	322.95	1.868	325.03	324.7	*2.3*	*1.96*	2.29	0.48
7500	313.42	322.58	322.79	1.874	324.54	324.54	*1.96*	*1.96*	1.42	0.7
7400	313.23	322.42	322.63	1.88		324.38		*1.96*	2	1.36
7300	313.04	322.28	322.48	1.888	324.23		*1.95*		1	2.07
7200	312.85	322.14	322.34	1.898	324.23	324.038	*2.09*		0.86	1.83
7100	312.66	321.99	322.19	1.906	323.94	323.94	*1.95*		0.94	1.98
7000	312.47	321.85	322.04	1.914	323.79	323.79	*1.94*	*1.94*	0.35	0.95

Table 11
Reach 7b – West Little Llagas Creek Diversion Channel
Levee Freeboard

River Sta	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	0.2EG Freeboard (ft)	Levee El Left (ft)	Levee El Right (ft)	L. Levee Frbrd (ft)	R. Levee Frbrd (ft)	L. Freeboard (ft)	R. Freeboard (ft)
6900	312.28	321.74	321.93	**1.93**	324.68	324.68	*2.94*	*2.94*	-0.56	-0.22
6800	312.09	321.66	321.84	**1.95**	324.59	324.59	*2.93*	*2.93*	-1.64	-1.64
6700	311.9	321.57	321.75	**1.97**	324.5	324.5	*2.93*	*2.93*	-1.4	-0.86
6600	311.71	321.47	321.64	**1.986**		323.4		*1.93*	3.3	0.19
6500	311.52	321.36	321.53	**2.002**		323.4		*2.04*	3.63	0.73
6400	311.33	321.25	321.41	**2.016**		323.2		*1.95*	3.52	1.72
6300	311.14	321.15	321.31	**2.034**	323.184				1.88	2.8
3200	307.62	317.72	317.87	**2.05**	319.77				1.89	2.18
3000	307.51	317.33	317.57	**2.012**	319.29		*1.96*		1.56	1.56
2900	307.46	317.21	317.45	**1.998**	319.21	319.21	*2*	*2*	1.26	1.65
2800	307.4	317.09	317.34	**1.988**	319.09	319.09	*2*	*2*	0.94	0.94
2700	307.35	316.97	317.22	**1.974**	318.97	318.97	*2*	*2*	0.73	0.73
2600	307.3	316.85	317.11	**1.962**	318.86	318.86	*2.01*	*2.01*	0.81	0.37
2500	307.24	316.73	316.99	**1.95**	318.74	318.74	*2.01*	*2.01*	0.23	0.23
2400	307.19	316.61	316.87	**1.936**	319.62	319.62	*3.01*	*3.01*	0.02	0.02
2300	307.14	316.49	316.75	**1.922**	319.5	319.5	*3.01*	*3.01*	-0.68	-1.05
2200	307.09	316.38	316.63	**1.908**	319.38	319.38	*3*	*3*	-1.24	-1.45
2100	307.03	316.26	316.51	**1.896**	319.26	319.26	*3*	*3*	-1.33	-1.26
2000	306.98	316.14	316.4	**1.884**	319.14	319.14	*3*	*3*	-2.02	-1.56
1900	306.93	316.02	316.28	**1.87**	319.02	319.02	*3*	*3*	-1.76	-1.76
1800	306.87	315.9	316.16	**1.858**	318.91	318.91	*3.01*	*3.01*	-1.64	-1.32
1700	306.82	315.76	316.04	**1.844**	318.77	318.77	*3.01*	*3.01*	-1.75	-1.37
1600	306.77	315.64	315.91	**1.828**	318.65	318.65	*3.01*	*3.01*	-1.63	-1.63
1500	306.71	315.5	315.79	**1.816**	318.52	318.52	*3.02*	*3.02*	-1.68	0.37
1400	306.66	315.38	315.66	**1.8**	318.44	318.44	*3.06*	*3.06*	-1.75	0.23
1300	304.53	315.34	315.56	**2.206**	318.36	318.36	*3.02*	*3.02*	-2.1	0.02
1200	304.4	315.27	315.48	**2.216**	318.29	318.29	*3.02*	*3.02*	-2.17	-1.05

4.4.4 Reach 7 Channel Stability

An integrated approach to bank stabilization for the proposed design will be employed, including the addition of native vegetation, vegetated rip-rap and bank shaping and bioengineering techniques within Reach 7, upstream of the diversion channel. An additional benefit from incorporating vegetative methods includes the creation of potential wildlife habitat while providing bank and toe stabilization.

The modified banks will be reshaped to provide a stable streambank with finished side slopes of 1V:2H to 1V:3H and replanted with native vegetation. Since the exposed streambank along the straight sections of the modified banks are susceptible to high flows prior to vegetation, appropriate vegetative streambank stabilization methods should be evaluated for suitability to the project. Vegetative stream bank stabilization methods such as brush mattresses, vegetated geogrids, vegetated rip-rap and other measures are possible effective bank stabilization techniques. Vegetated rip-rap, a typical section shown on Plate 21a, is flexible and not impaired by slight movement from settlement and where appropriate should be used to provide toe and bank protection. Brush mattresses would provide an immediate protective cover and aid in the restoration of riparian vegetation and streamside habitat. A typical brush mattress schematic is shown on Plate 21b, Figure 1.

The proposed diversion channel design, Reach 7a, consists of a two channel configurations, a trapezoidal section with levees and a two-stage flood control channel, with left and right benches. The proposed trapezoidal cross-section assumes a Manning n-value of 0.045. For the two-stage flood control channel in Reach 7a, the design assumes a Manning n-value of 0.045 within the channel-forming discharge channel and a Manning n-value of 0.06 within the high-flow section of channel. It was determined to be equivalent to a composite Manning n-value of 0.05.

Upstream of the diversion channel in Reach 7b, the proposed design, again, consists of two channel configurations, a trapezoidal cross-section and a two-stage flood control channel, with left and right benches. The proposed trapezoidal cross-section assumes a Manning n-value of 0.045. For the two-stage flood control channel in Reach 7b, the design assumes a Manning n-value of 0.045 within the channel-forming discharge channel and a Manning n-value of 0.06 within the high-flow section of channel. It was determined to be equivalent to a composite Manning n-value of 0.05.

Throughout Reach 7, a Mannings n-value of 0.045 within the proposed cross-section sallow for a low to medium amount of brushy, moderately dense vegetation along the banks and no significant amount of vegetation along the channel bottom. A Mannings n-value of 0.6 in the high flow section allows for a medium – low amount of vegetation similar to 1- to 2-year old willow trees inter-grown with weeds and brush along the benches and side slopes.

The suggested maximum permissible mean channel velocities for grass lined earth; with slopes less than 5% is 5.0 feet per second. The maximum and minimum channel velocities in Reach 7a are 3.1 and 4.3 feet per second, respectively and the maximum and minimum channel velocities in Reach 7b are approximately 3.1 and 4.8 feet per second, respectively. Both well within the maximum permissible mean. Without further sediment transport analysis, based on maximum permissible velocities, under design conditions the Diversion channel should be fairly resistant to scour. A velocity plot for Reach 7 is shown on Plate 12.

5.0 HYDRAULIC ANALYSIS FOR LLAGAS CREEK - REACHES 4, 5 AND 6

The project along the Llagas Creek portion of the project, Reaches 4, 5 and 6, consists of 6.53 miles of channel improvement work, to provide channel stability, increased capacity, to provided for existing capacity plus capacity to preclude induced flooding from the future upstream improvements in Reaches 7 and 8 and includes various stream enhancement features. Channel width, throughout Reaches 4, 5 and 6 is constrained by right-of-way limitations. The chosen design incorporates widening and deepening of the existing channel while maintaining the existing alignment.

The proposed design consists of removing the six rock chute drop structures, included in the NRCS design, to provide free passage of migratory steelhead. The NRCS drop structures were located within Reaches 4 and 6, to minimize channel excavation and decrease the channel gradient to create a more stabile channel, with lower velocities. Removal of the NRCS drop structures facilitates more extensive deepening of the channel and slightly steeper channel gradients. However, incorporating higher channel roughness and maintaining the existing channel sinuosity, which was reduced in the NRCS design, kept channel velocities within acceptable limits. On the order of 4.5 feet per second.

In 2002, the U.S. Fish and Wildlife Service (USFWS) surveyed the project reaches as part of the Habitat Evaluation Procedures (HEP) Application and determined the habitat quality, expressed by a Habitat Suitability Index (HSI). The HSI was determined for both the left and right banks for Llagas Creek. To aid the District in verifying the bank, which would have the least impacts, the mean HSI was determined, then plotted and a trend line was determined. The mean HSI, by reach are included on Plates 22 –24. These plots are summarized in Plate 25. From Plate 25, it can be seen that in Reach 4 the most valuable habitat exists on the right bank, in Reaches 5 and 6 both banks have approximately equivalent significant value. Therefore, in keeping with the NRCS design, is as much as possible, in general the single bank modification of the left bank, is the preferred method of channel enlargement in Reaches 4, 5 and 6b. Reach by reach descriptions for Llagas Creek are included in the following sections.

5.1 REACH 6 – Diversion Channel to 700 feet upstream Hwy 101

Llagas Creek, Reach 6 is situated within the agricultural areas of Morgan Hill and San Martin. Reach 6 has become a near perennial stream reach due to releases from Chesbro Reservoir, providing very favorable conditions for the establishment of potential steelhead habitat within the channel. Reach 6 is subdivided into two reaches, Reach 6a and 6b. Reach 6a, is located between the West Little Llagas Creek diversion channel and Monterey Hwy. Reach 6b spans the length of Llagas Creek from Monterey Hwy to 700 feet upstream of Highway 101.

5.1.1 Reach 6 Alignment

Llagas Creek, Reach 6 is a total of 3.7 miles in length. The total length of Reach 6a is 0.5 miles and the total length of Reach 6b is 3.2 miles. Reach 6 has an existing sinuosity of 1.3. The existing Llagas Creek channel alignment has been maintained throughout Reach 6.

5.1.2 Reach 6 Hydrology

The design criteria for Llagas Creek in Reach 6, requires the project to provide existing capacity plus capacity to preclude induced flooding from the upstream improvements to Reaches 7 and 8. No specific level of protection was assigned to these criteria in the workplan supplement. The NRCS study indicates that the existing level of protection for Reach 6 was accepted to be about the 10-year event. In accordance with the NRCS wathershed plan, the level of protection assigned to Reach 6 is the 10% flood event or the 10-yr event, 3,300 cfs. The peak flows for the channel in Reach 6 are shown in Table 12. For comparison, the NRCS 1% & 10% flows are also included in Table 12.

Table 12
Llagas Creek
Reach 6 Design Flow Rates

Location	Drainage Area (sq. mi)	50% Peak (cfs)		10% Peak (cfs)		1% Peak (cfs)	
		USACE	NRCS	**USACE Design Q**	NRCS Design Q	USACE	NRCS
Downstream West Little Llagas Creek Diversion Channel	33.24	1100	-	3000	3800	5500	5850
Upstream East Little Llagas Creek	35.5	1300	-	**3300**	4100	5800	6000

5.1.3 Reach 6 Hydraulic Design

The design objective for this reach is to provide existing capacity plus capacity to preclude induced flooding from upstream improvements. Other design considerations for Reach 6 are, the removal of the maintenance roads within the channel and the removal of four drop structures from the NRCS design to facilitate free passage of fish, improved habitat for resident and endangered species, the addition of a channel-forming discharge channel (where possible), limit channel widening to one side of channel and set back levees. The 2-year recurrence interval was used to determine the effective discharge in the design of the channel-forming discharge channel. The design conditions assume that the existing arrundo is completely eradicated from Reach 6. HEC-RAS was used to determine the water

surface profiles for subcritical flow, the water surface profile for Reach 6 is shown on Plates 25. The channel velocities in Reach 6 are shown on Plate 26.

Reach 6a consists of 2,562-ft, 0.5 miles, of set back levee on the left overbank, looking downstream, from Monterey Hwy to the West Little Llagas diversion channel. The set back levees will leave the existing channel undisturbed and eliminateds any impacts to the stream corridor upstream of Monterey Highway. The right overbank in naturally high ground and eventually ties into Silveira Lake. A channel n-value of 0.07 and a overbank n-value of 0.05 were used for reach 6a. The channel has a general natural slope of 0.0036 ft/ft. The average channel velocities in Reach 7a are 4.2 feet per second. A typical section is shown on Plate 27.

The levee along the left overbank would tie into the diversion channel levee. The minimum freeboard necessary for Reach 6b, for is 3.5 feet, based the SVCWD freeboard requirements, Policy 3-218, A(1), where the design water surface elevation is above natural ground. The levee will provide maintenance access to the area and consists of 1V:2H side slopes with a 12 ft top width, varying from 5 – 6 feet in height. The levee in Reach 6a will provide protection against the 100-year flood, so that area north of the levee will not be prone to induced flooding from Llagas Creek downstream of West Little Llagas Creek. The proposed freeboard requirements for Reach 6a are shown in Table 13.

The proposed design in Reach 6b consists of a two-stage flood control channel, with left and/or right benches, requiring deepening, widening and filling of the existing channel. Channel widening was limited to left side of the channel where possible. A restored more natural channel with vegetated and a left bank bench, 26 feet wide, with either 1V:3H or 1V:4H side slopes and 2-year channel-forming discharge channel, with a bottom width of 30 – 36 feet, to allow sediment movement downstream, is proposed throughout most of Reach 6b. At locations along Reach 6b, where enough right-of-way was available, a bench was added to the right side of the 2-year channel-forming discharge channel. The design assumes a Manning n-value of 0.05 within the channel-forming discharge channel and a Manning n-value of 0.07 within the high-flow section of channel. It was determined to be equivalent to a composite Manning n-value of 0.06. The average channel velocities in Reach 6b are approximately 4.5 feet per second. Maintenance access would be along the top of bank. Typical sections for the different channel configurations are shown on Plates 28 and 29.

Table 13

Reach 6a – Llagas Creek
Set Back Levees Freeboard

River Sta	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	0.2EG Freeboard (ft)	Levee El Left (ft)	L. Levee Frbrd (ft)	L. Freeboard (ft)
71800	304	314.91	315.18	2.236	318.42	3.51	*-0.91*
71700	304	314.71	314.94	2.188	318.22	3.51	*-3.71*
71600	304	314.43	314.71	2.142	317.95	3.52	*-3.83*
71500	303.6	314.15	314.44	2.168	317.67	3.52	*-3.19*
71400	303	313.82	314.13	2.226	317.33	3.51	*-0.92*
71300	303.46	313.54	313.8	2.068	317.06	3.52	*-3.54*
71200	304	313.36	313.54	1.908	316.88	3.52	*-4.36*
71100	304	313.28	313.37	1.874	316.8		*-4.28*
71000	304	313.14	313.27	1.854	316.67	3.53	*-4.14*
70900	303.73	313.05	313.15	1.884	316.59	3.54	*-5.05*
70800	302.28	312.95	313.05	2.154	316.49	3.54	*-5.79*
70700	302	312.87	312.96	2.192	316.4	3.53	*-5.87*
70600	302	312.7	312.84	2.168	316.24		*-4.66*
70500	302	312.34	312.61	2.122	315.89	3.55	*-4.43*
70400	302	312.05	312.32	2.064	315.61	3.56	*-6.05*
70300	301.51	311.61	311.98	2.094	315.19	3.58	*-3.61*
70200	300.7	311.38	311.64	2.188	314.98	3.6	*-3.38*
70100	300.6	311.11	311.38	2.156	314.72	3.61	*-5.11*
70000	300.49	310.81	311.13	2.128	314.45	3.64	*-4.81*
69900	299	310.53	310.86	2.372	314.19	3.66	*-5.2*
69800	298.5	310.07	310.51	2.402	313.78	3.71	*-5.07*
69700	298	309.59	310.08	2.416	313.38	3.79	*-4.59*
69600	298.37	309.35	309.67	2.26	313.17	3.82	*-5.35*
69500	297.27	308.98	309.36	2.418	312.87	3.89	*-4.98*
69400	296.16	308.76	309.08	2.584	312.69	3.93	*-7.76*
69300	295.5	308.1	308.75	2.65	312.11	4.01	*-1.1*
69237.65	294.66	307.91	308.48	2.764	311.86	3.95	*2.15*

Downstream of San Martin Avenue, from station 624+00 to station 616+00, the existing stream alignment runs through the middle of several properties. To avoid leaving the property owners with segmented or very small inaccessible parcels the right bank was shifted north, up to 25-feet north. This maintained the existing channel alignment and allowed for extensive widening of the high flow section of the channel. This allowed for a more natural channel with vegetated and minimally maintained left and right bank benches, 10 – 50 feet wide, with 1V: 3H side slopes and a 2-year channel-forming discharge channel, with a bottom width of 36 feet. The design assumes a Manning n-value of 0.05 within the channel-forming discharge channel and a Manning n-value of 0.1 within the high-flow section of channel. It was

determined to be equivalent to a composite Manning n-value of 0.08. The average channel velocities in this section of Reach 6b are 3.5 feet per second. Maintenance access would be along the top of bank. A typical section is shown on Plate30.

There are five existing bridge crossings within Reach 6, Monterey Hwy, SPRR, Llagas Avenue, San Martin Avenue and Church Avenue. The existing bridges are capable of conveying the design flood event. Only minor deepening, approximately 2 feet, of the existing channel in the vicinity of the bridges will be necessary. The existing bridge information is included in Table 14.

The channel design summary table and various calculations for the proposed design are included in Appendix A. The HEC-RAS summary output and cross-section plots for Llagas Creek are included Appendix D.

Table 14
Reach 6 - Llagas Creek
Existing Bridges

Reach 7 Location	Type of X-ing	Roadway Width (ft)	Existing Bridge	
			Pier Size (ft)	Number of Piers
Monterey Hwy	Bridge	80	1.5	6
SPRR	Bridge	19	1.0	8
Llagas Avenue	Bridge	22	2.5	1
San Martin Avenue	Bridge	37	1.2	2
Church Avenue	Bridge	37	1.3	4

5.1.4 Reach 6 Channel Stability

An integrated approach to bank stabilization for the proposed design will be employed, including the addition of native vegetation, revetment systems, vegetated rip-rap, vegetated gabions and bank shaping and planting within Reach 6b. An additional benefit from incorporating vegetative methods includes the creation of potential habitat for fish and wildlife while providing bank and toe stabilization. Reach 6a will not incorporate bank stabilization measures since set back levees have been incorporated into the design.

The proposed design in Reach 6b consists of a two-stage flood control channel, with left and/or right benches. For most of Reach 6b, the design assumes a Manning n-value of 0.05 within the channel-forming discharge channel and a Manning n-value of 0.07 within the high-flow section of channel. A Mannings n-value of 0.05 in the effective discharge channel allows for a medium amount of brushy, moderately dense

vegetation along the banks and no significant amount of vegetation along the channel bottom. It was determined to be equivalent to a composite Manning n-value of 0.06.

Downstream of San Martin, the design assumes a Manning n-value of 0.05 within the channel-forming discharge channel and a Manning n-value of 0.1 within the high-flow section of channel. It was determined to be equivalent to a composite Manning n-value of 0.08. A Mannings n-value of 0.7 in the high flow section allows for a medium amount of vegetation similar to 1- to 2-year old willow trees inter-grown with weeds and brush along the benches and side slopes. Downstream of San Martin Avenue, a Mannings n-value of 0.1 in the high flow section allows for a large amount vegetation similar 8- to 10- year old willow trees inter-grown with weeds and brush along the benches and side slopes.

In general the right bank will be left undisturbed as much as possible to protect the existing vegetation and the left bank will be modified to provide the necessary capacity. The modified banks will be reshaped to provide a stable streambank with finished side slopes of 1V:3H or greater and replanted with native vegetation. Since the exposed streambank along the straight sections of the modified banks are susceptible to high flows prior to vegetation, appropriate vegetative streambank stabilization methods should be evaluated for suitability to the project. Vegetative stream bank stabilization methods such as brush mattresses, vegetated geogrids, vegetated rip-rap and other measures are possible effective bank stabilization techniques. Vegetated rip-rap, a typical section shown on Plate 21a, is flexible and not impaired by slight movement from settlement and where appropriate should be used to provide toe and bank protection. Brush mattresses would provide an immediate protective cover and aid in the restoration of riparian vegetation and streamside habitat. A typical brush mattress schematic is shown on Plate 21b, Figure 1.

The existing channel meander of Reach 6a will be left undisturbed. In maintaining a sinuous channel, the outside bank at bends in the channel require toe and bank protection, since they are especially susceptible to erosion. There are 19 changes in direction in Reach 6b, of these 19 bends, 9 are located on the undisturbed bank and 10 are located on the impacted bank, for a total of 5400-ft of streambank protection. To provide bank and toe protection as well as improved habitat, by decreasing velocities along the bank, the rootwad and boulder revetment technique should be used along the disturbed toe and the upper bank replanted with vegetated geogrid. It is anticipated that approximately 10 logs and 20 boulders per 100 lineal feet of bank would be necessary to provide the essential streambank and toe protection. To further avoid disturbance to existing bank, vegetated rip-rap should be used provide toe protection along the undisturbed bank.

On meandering gravel streams, such as the conditions on Reach 6b, the natural creation of pool and riffles pools occur at irregular intervals. Pools are located in bends and riffles in the straight sections between bends. The use of the rootwad and boulder revetments to protect the streambank and toe along the outside of bends

within the natural channel pattern will also induce the creation of pools and riffles and improve habitat diversity. Shown in Table 15 are the locations and length of section and the type of protection to be installed along the meander bend.

Table 15
Reach 6 Llagas Creek
Streambank Protection

No.	Location	Left Bank (feet)	Right Bank (feet)	Type*	RWB Quanity (logs+ boulders)
1	686+00 – 683+00	300		VRR	-
2	678+00 – 676+50		150	RWB	15+30
3	668+00 – 663+00	500		VRR	-
4	653+00 – 651+00		200	RWB	20+40
5	648+00 – 646+50	150		RWB	15+30
6	643+00 – 640+50		250	VRR	-
7	637+00 – 632+00	500		RWB	50+100
8	622+00 – 614+50		750	RWB	75+150
9	611+00 – 608+00	300		RWB	30+60
10	607+00 – 606+00		100	VRR	-
11	602+00 – 601+50	50		RWB	5+10
12	595+00 – 592+00		300	RWB	30+60
13	580+50 – 578+50	200		VRR	-
14	575+00 – 572+00		300	RWB	30+60
15	566+00 – 564+00	200		VRR	-
16	559+00 – 558+00		100	VRR	-
17	551+00 – 550+00	100		RWB	10+20
18	542+00 – 534+00		800	VRR	-
19	529+50 –528+00	150		RWB	15+30
R6 Total Streambank Protection		*2450*	*2950*	*Total R6 RWB*	*295+590*

*Type of streambank protection to be used at that location, Vegetated Rip-Rap (VRR) or Rootwad/Boulder Revetment (RWB).

The suggested maximum permissible mean channel velocities for grass lined earth; with slopes less than 5% is 5.0 feet per second. The maximum and minimum channel velocities in Reach 6b are 3.0 to 5.5 feet per second, respectively. The mean channel velocity of Reach 6b is 4.5 feet per second, well within the maximum permissible mean. Without further sediment transport analysis, based on maximum permissible velocities, under design conditions, Llagas Creek along Reach 6 should be fairly resistant to scour.

5.2 REACH 5 – 700 feet Upstream Hwy 101 to East Little Llagas Creek

Llagas Creek, Reach 5 is situated within the agricultural area of San Martin, in the vicinity of Highway 101. It is the shortest reach within the project limits, less than one mile in length. Reach 5 is typically dry in the summer and fall months and spans the length of Llagas Creek from East Little Llagas Creek to 700 feet upstream of Highway 101.

5.2.1 Reach 5 Alignment

Llagas Creek, Reach 5 is a total of 0.47 miles in length and has a sinuosity of 1.2. The existing Llagas Creek channel alignment has been maintained throughout Reach 5.

5.2.2 Reach 5 Hydrology

The design criteria for Llagas Creek in Reach 5, requires the project to provide existing capacity plus capacity to preclude induced flooding from the upstream improvements to Reaches 7 and 8. No specific level of protection was assigned to these criteria in the workplan supplement. The NRCS study indicates that the existing level of protection for Reach 5 was accepted to be about the 10-year event. In accordance with the NRCS wathershed plan, the level of protection assigned to Reach 5 is the 10% flood event or the 10-yr event, 3,300 cfs. The peak flows for the channel in Reach 5 are shown in Table 16. For comparison, the NRCS 1% & 10% flows are also included in Table 16.

Table 16
Llagas Creek
Reach 5 Design Flow Rates

Location	Drainage Area (sq. mi)	50% Peak (cfs)		10% Peak (cfs)		1% Peak (cfs)	
		USACE	NRCS	**USACE Design Q**	NRCS Design Q	USACE	NRCS
Upstream East Little Llagas Ck	35.5	1300	-	**3300**	4100	5800	6000

5.2.3 Reach 5 Hydraulic Design

The design objective for Reach 5 is to provide existing capacity plus capacity to preclude induced flooding from upstream improvements. No specific level of protection was assigned to Llagas Creek in the watershed plan, however the 10-year level of protection has been assigned to Reach 5. Other design considerations for Reach 5 were, the removal of the maintenance roads within the channel, improved habitat for resident and endangered species, the addition of a channel-forming

discharge channel (where possible) and limited channel widening to one side of channel. The 2-year recurrence interval was used to determine the effective discharge in the design of the channel-forming discharge channel. HEC-RAS was used to determine the water surface profiles for subcritical flow, the water surface profile for Reach 5 is shown on Plates 25.

The improvements to Reach 5 consist of deepening and widening of the channel. The channel widening was limited to left side of the channel in Reach 5. A restored more natural channel with vegetated and minimally maintained left bank bench, 26 feet wide, with either 1V:3H side slopes and 2-year channel-forming discharge channel, with a bottom width of 30 feet and 6 – 7 feet deep, to allow sediment movement downstream, is proposed throughout reach 5. The design assumes a Manning n-value of 0.05 within the channel-forming discharge channel and a Manning n-value of 0.07 within the high-flow section of channel. It was determined to be equivalent to a composite Manning n-value of 0.06. The average channel velocities in this section of Reach 5 are 4.6 feet per second. Maintenance access would be along the top of bank. A typical section for Reach 5 is shown on Plates 28.

There are two existing bridge crossings within Reach 5, the Northbound and Southbound Highway 101 bridges. The existing bridges are capable of conveying the design flood event. Only minor deepening, approximately 2.5 feet, of the existing channel under bridges will be necessary. The existing bridge information is included in Table 17.

Table 17
Reach 5 - Llagas Creek
Existing Bridges

Reach 7 Location	Type of X-ing	Roadway Width (ft)	Existing Bridges	
			Pier Size (ft)	Number of Piers
Northbound Hwy 101	Bridge	50	3	1
Southbound Hwy 101	Bridge	52	3	1

The channel design summary table and various calculations for the proposed design are included in Appendix A. The HEC-RAS summary output and cross-section plots for Llagas Creek are included in Appendix D.

5.2.4 Reach 5 Channel Stability

An integrated approach to bank stabilization for the proposed design will be employed, including the addition of native vegetation, revetment systems, vegetated rip-rap, vegetated gabions and bank shaping and planting within Reach 5. An

additional benefit from incorporating vegetative methods includes the creation of potential habitat for fish and wildlife while providing bank and toe stabilization.

The proposed design in Reach 5 consists of a two-stage flood control channel, with left and/or right benches. For Reach 5, the design assumes a Manning n-value of 0.05 within the channel-forming discharge channel and a Manning n-value of 0.07 within the high-flow section of channel. It was determined to be equivalent to a composite Manning n-value of 0.06. A Mannings n-value of 0.05 in the effective discharge channel allows for a medium amount of brushy, moderately dense vegetation along the banks and no significant amount of vegetation along the channel bottom. A Mannings n-value of 0.7 in the high flow section allows for a medium amount of vegetation similar to 1- to 2-year old willow trees inter-grown with weeds and brush along the benches and side slopes.

In Reach 5 the right bank will be left undisturbed to protect the existing vegetation and the left bank will be modified to provide the necessary capacity. The modified banks will be reshaped to provide a stable streambank with finished side slopes of 1V:3H or greater and replanted with native vegetation. Since the exposed streambank along the straight sections of the modified banks are susceptible to high flows prior to vegetation, appropriate vegetative streambank stabilization methods should be evaluated for suitability to the project. Vegetative stream bank stabilization methods such as brush mattresses, vegetated geogrids, vegetated rip-rap and other measures are possible effective bank stabilization techniques. Vegetated rip-rap, a typical section shown on Plate 21a, is flexible and not impaired by slight movement from settlement and where appropriate should be used to provide toe and bank protection. Brush mattresses would provide an immediate protective cover and aid in the restoration of riparian vegetation and streamside habitat. A typical brush mattress schematic is shown on Plate 21b, Figure 1.

The existing channel meander of Reach 5 will be left undisturbed. In maintaining a sinuous channel, the outside bank at bends in the channel require toe and bank protection, since they are especially susceptible to erosion. There are 2 changes in direction in Reach 5, of these 2 bends, one is located on the undisturbed bank and one is located on the impacted bank. To provide bank and toe protection as well as improved habitat, by decreasing velocities along the bank, the rootwad and boulder revetment technique should be used along the disturbed toe and the upper bank replanted with vegetated geogrid. It is anticipated that approximately 10 logs and 20 boulders per 100 lineal feet of bank would be necessary to provide essential streambank and toe protection. To further avoid disturbance to existing bank, vegetated rip-rap should be used provide toe protection along the undisturbed bank.

On meandering gravel streams, such as the conditions on Reach 5, the natural creation of pools and riffles occur at irregular intervals. Pools are located in bends and riffles in the straight sections between bends. The use of the rootwad and boulder revetments to protect the streambank and toe along the outside of bends within the natural channel pattern will also induce the creation of pools and riffles and improve

habitat diversity. Shown in Table 18 are the locations and lengths of section and the type of protection to be installed along the meander bend.

Table 18
Reach 5 Llagas Creek
Streambank Protection

No.	Location	Left Bank (feet)	Right Bank (feet)	Type*	RWB Quanity (logs+ boulders)
1	624+50 – 621+00		350	VRR	-
2	504+00 – 501+00	300		RWB	30+60

*Type of streambank protection to be used at that location, Vegetated Rip-Rap (VRR) or Rootwad/Boulder Revetment (RWB).

The suggested maximum permissible mean channel velocity for a gravel channel is 6.0 feet per second. The maximum and minimum channel velocities in Reach 5 are 4.1 to 5.0 feet per second, respectively. The mean channel velocity of Reach 5 is 4.5 feet per second, well within the maximum permissible mean. Without further sediment transport analysis, based on maximum permissible velocities, under design conditions, Llagas Creek along Reach 5 should be fairly resistant to scour.

5.2.5 REACH 4 - East Little Llagas Creek to Buena Vista Avenue

Llagas Creek, Reach 4 is situated within the agricultural area of San Martin and connects the project with the Lower Llagas Creek Project already completed by the NRCS at Buena Vista Avenue. Reach 4 is the most downstream reach of the project and it also has the smallest existing conveyance capacity in the project watershed. Reach 4 is typically dry in the summer and fall months and is located between East Little Llagas Creek and Buena Vista Avenue, just upstream of Panther Creek.

5.2.6 Reach 4 Alignment

Llagas Creek, Reach 4 is a total of 2.36 miles in length and is the most sinuous reach within the project, with a sinuosity of 1.4. The existing Llagas Creek channel alignment has been maintained throughout Reach 4.

5.2.7 Reach 4 Hydrology

The design criteria for Llagas Creek in Reach 4, requires the project to provide existing capacity plus capacity to preclude induced flooding from the upstream improvements to Reaches 7 and 8. No specific level of protection was assigned to these criteria in the workplan supplement. The NRCS study indicates that the existing level of protection for Reach 4 was accepted to be about the 10-year event,

however, upon further research the actual design capacity used in the NRCS design was closer to the 5-year event.

The NRCS design capacity for Reach 4 was determined by comparing the pre-1970, prior to CalTrans excavation and post-1970 flow rates, subsequent to CalTrans excavation, to the PL-566 flow rates at the existing bottleneck upstream of Masten Avenue. The resulting NRCS flow rate for Reach 4 was determined to be 4,000 cfs.

The same approach for determining the capacity for Reach 4 was duplicated for this study using the updated hydrology. However, the bottleneck is no longer located upstream of Masten Avenue, the bottleneck currently resides downstream of Rucker Avenue. Therefore, the pre-1970 and post-1970 flow rates were compared to the new flow rates at the current bottleneck downstream of Rucker Avenue, resulting in a revised design capacity in Reach 4 of 3,450 cfs.

In accordance with the NRCS wathershed plan, the level of protection assigned to Reach 5 is the 5-yr event, 3450 cfs. The design flows for the channel in Reach 4 are shown in Table 18. For comparison, the NRCS 1% & 10% flows are also included in Table 19.

Table 19
Llagas Creek
Reach 4 Design Flow Rates

Location	Drainage Area (sq. mi)	Design Flow (cfs)	
		USACE	NRCS
Reach 4	61.71	3450	4000

5.2.8 Reach 4 Hydraulic Design

The design objective for Reach 4 is to provide existing capacity plus capacity to preclude induced flooding from upstream improvements. No specific level of protection was assigned to Llagas Creek in the watershed plan, however a 5-year level of protection has been assigned to Reach 4. Other design considerations for Reach 4 were, the removal of the maintenance roads within the channel and the removal of two drop structures from the NRCS design to facilitate free passage of fish, improved habitat for resident and endangered species and limited channel widening to one side of channel. For Reach 4 the 2-year recurrence interval was not used to determine the effective discharge in the design of the channel-forming discharge channel. The 5-year recurrence interval was used as the effective discharge channel since it would require additional right-of-way to use the 2-year recurrence interval. HEC-RAS was used to determine the water surface profiles for subcritical flow, the water surface profile for Reach 4 is shown on Plate 31.

The improvements to Reach 4 consist of deepening and widening of the channel. The channel widening in general was limited to left side of the channel, except in 3 locations where the channel was widened on the right bank to avoid taking homes and/or large trees. The channel configuration throughout this section of Reaches 4 is purely dependent on the right-of-way limitation. The proposed design consists of a trapezoidal cross section has a 25-ft bottom width, 1V:3H side slopes and a 9 to 13-ft depth. The design of the trapezoidal cross section assumes a Manning n-value of 0.05. The average channel velocities for Reach 4 are 4.8 feet per second. Maintenance access would be along the top of bank. A typical section is shown on Plate 32.

There are three existing bridge crossings within Reach 4, Masten Avenue, Rucker Avenue and Buena Vista Avenue. The existing bridges are capable of conveying the design flood event. Only minor deepening, approximately 0.5 - 2 feet, of the existing channel under bridges will be necessary. Existing bridge information is included in Table 20.

The channel design summary table and various calculations for the proposed design are included in Appendix A. The HEC-RAS summary output and cross-section plots for Llagas Creek are included in Appendix D

Table 20
Reach 4 - Llagas Creek
Existing Bridges

Reach 7 Location	Type of X-ing	Roadway Width (ft)	Existing Bridges	
			Pier Size (ft)	Number of Piers
Masten Avenue	Bridge	19	1.5	1
Rucker Avenue	Bridge	42	1.5	3
Buena Vista Avenue	Bridge	34	1.25	2

5.2.9 Reach 4 Channel Stability

An integrated approach to bank stabilization for the proposed design will be employed, including the addition of native vegetation, revetment systems, vegetated rip-rap, vegetated gabions and bank shaping and planting within Reach 4. An additional benefit from incorporating vegetative methods includes the creation of potential habitat for fish and wildlife while providing bank and toe stabilization.

The improvements to Reach 4 consist of deepening and widening of the channel. The channel widening in general was limited to left side of the channel, except in 3 locations where the channel was widened on the right bank to avoid taking homes.

The proposed design consists of a trapezoidal cross section has a 25-ft bottom width, 1V:3H side slopes and a 9 to 13-ft depth.

The proposed design in Reach 4 consists of a trapezoidal cross section. The design in Reach 4 assumes a Manning n-value of 0.05 within the channel-forming discharge channel. A Mannings n-value of 0.05 in the effective discharge channel allows for a medium amount of brushy, moderately dense vegetation along the banks and no significant amount of vegetation along the channel bottom.

On meandering gravel streams, such as the conditions on Reach 4, the natural creation of pool and riffles pools occur at irregular intervals. Pools are located in bends and riffles in the straight sections between bends. The use of the rootwad and boulder revetments to protect the streambank and toe along the outside of bends within the natural channel pattern will also induce the creation of pools and riffles and improve habitat diversity.

In general the right bank will be left undisturbed as much as possible to protect the existing vegetation and the left bank will be modified to provide the necessary capacity. The modified banks will be reshaped to provide a stable streambank with finished side slopes of 1V:2H or greater and replanted with native vegetation. Since the exposed streambank along the straight sections of the modified banks are susceptible to high flows prior to vegetation, appropriate vegetative streambank stabilization methods should be evaluated for suitability to the project. Vegetative stream bank stabilization methods such as brush mattresses, vegetated geogrids, vegetated rip-rap and other measures are possible effective bank stabilization techniques. Vegetated rip-rap, a typical section shown on Plate 21a, is flexible and not impaired by slight movement from settlement and where appropriate should be used to provide toe and bank protection. Brush mattresses would provide an immediate protective cover and aid in the restoration of riparian vegetation and streamside habitat. A typical brush mattress schematic is shown on Plate 21b, Figure 1.

The existing channel meander of Reach 4 will be left undisturbed. In maintaining a sinuous channel, the outside bank at bends in the channel require toe and bank protection, since they are especially susceptible to erosion. There are 14 changes in direction in Reach 4, of these 14 bends, 7 are located on the undisturbed bank and 7 are located on the impacted bank, for a total of 5750 feet of streambank protection. To provide bank and toe protection as well as improved habitat, by decreasing velocities along the bank, the rootwad and boulder revetment technique should be used along with the vegetated rip-rap and boulder clusters techniques. It is anticipated that approximately 10 logs and 20 boulders per 100 lineal feet of bank would be necessary to provide essential streambank and toe protection. In Reach 6 the type of streambank protection was determined by the bank, however, in Reach 4 the type of streambank protection was determined by location. There are several homes built next to the top of bank and several other locations where it may be more appropriate to use the rootwad and boulder revetment technique, due to the severity of the bend. Vegetated rip-rap with boulder clusters will used at locations where the

channel makes mild bends or near bridges. Additionally in Reach 4, vegetated gabions will be necessary to avoid impacting a private residence. Shown in Table 21 are the locations, length of section and the type of protection to be installed along the meander bend.

Table 21
Reach 4 Llagas Creek
Streambank Protection

No.	Location	Left Bank (feet)	Right Bank (feet)	Type*	RWB Quanity (logs+ boulders)
1	500+00 – 498+00		200	RWB	20+40
2	496+00 – 493+00	300		RWB	30+60
3	484+00 –481+00		300	RWB	30+60
4	477+00 – 471+00	600		RWB	60+120
5	465+00 – 464+00		100	VRR	-
6	461+00 – 460+00	100		VRR	-
7	458+00 – 456+50		150	VRR	-
8	444+50 – 442+50	200		VRR	-
9	442+50 – 440+00	250		VG	-
10	440+00 – 435+00	500		VRR	-
11	429+00 – 423+00		600	RWB	60+120
12	419+00 – 413+00		600	RWB	60+120
13	409+00 – 402+50	650		RWB	65+130
14	398+50 – 392+50		600	RWB	60+120
15	390+50 – 390+00	50		VRR	-
16	398+25 – 397+25		50	VRR	-
17	384+50 – 379+50	500		RWB	50+100
R4 Total length of Streambank Protection		*3150*	*2600*	*Total R4 RWB*	*435+870*

*Type of streambank protection to be used at that location, Vegetated Rip-Rap (VRR), Vegetated Gabions (VG) or Rootwad/Boulder Revetment (RWB).

The suggested maximum permissible mean channel velocity for a gravel channel is 6.0 feet per second. The maximum and minimum channel velocities in Reach 4 are 2.9 to 5.2 feet per second, respectively. The mean channel velocity of Reach 4 is 4.8 feet per second, well within the maximum permissible mean. A plot of the channel velocities in Reach 4 is included in Plate 26. Without further sediment transport analysis, based on maximum permissible velocities, under design conditions, Llagas Creek along Reach 4 should be fairly resistant to scour.

5.3 HYDRAULIC ANALYSIS FOR EAST LITTLE LLAGAS CREEK – REACH 14

The project along the East Little Llagas Creek portion of the project, Reaches 14 consists of 3.4 miles of channel improvement work, to provide channel stability, increased capacity to provided for existing capacity plus capacity to preclude induced flooding from the future upstream improvements in Reaches 14. Channel width, throughout Reach 14 is constrained by right-of-way limitations and the channel gradient is constrained by existing culvert inverts. The chosen design incorporates widening and deepening of the existing channel while maintaining the existing alignment.

5.3.1 REACH 14 – Llagas Creek to 2400 feet upstream of San Martin Avenue

Reach 14, is the only project area located along East Little Llagas Creek and is a tributary to the main branch Llagas Creek. Reach 14 is situated within the agricultural area of San Martin, downstream of the Madrone Channel and Tennant Creek. Reach 14 is an excavated channel that was straightened and realigned by CalTrans in the 1970's when building Hwy 101. Reach 14 is typically dry in the summer and fall months and spans the length of East Little Llagas Creek from the confluence with Llagas Creek to just upstream of Middle Avenue at West Little Llagas Creek at Highway 101.

5.3.2 Reach 14 Alignment

East Little Llagas Creek, Reach 14 is a total of 3.4 miles in length, with a sinuosity of 1.0. The existing East Little Llagas Creek channel alignment has been maintained throughout Reach 14.

5.3.3 Reach 14 Hydrology

The design criteria for Llagas Creek in Reach 14, requires the project to provide existing capacity plus capacity to preclude induced flooding from the upstream work. No specific level of protection was assigned to these criteria in the workplan supplement. The NRCS study indicates that the existing level of protection for Reach 14 was accepted to be about the 10-year event. In accordance with the NRCS wathershed plan, the level of protection assigned to Reach14 is the 10% flood event or the 10-yr event. The peak flows and design flow rates throughout Reach 14 are shown in Table 22. For comparison, the NRCS 1% & 10% flows are also included in Table 22.

Table 22
East Little Llagas Creek
Reach 14 Design Flow Rates

Location	Drainage Area (sq. mi)	50% Peak (cfs)		10% Peak (cfs)		1% Peak (cfs)	
		USACE	NRCS	**USACE Design Q**	NRCS Design Q	USACE	NRCS
Corralitos Ck	6.58	1490	-	**1600**	1450	2115	2533
San Martin Ck	14.54	1427	-	**2550**	2930	4051	5250
Church Ck	18.96	1187	-	**3150**	3580	5211	6370
Llagas Ck	20.97	929	-	**3450**	3830	5775	6913

5.3.4 Reach 14 Hydraulic Design

The design objective for Reach 14 is to provide existing capacity plus capacity to preclude induced flooding from future upstream improvements. No specific level of protection was assigned to Llagas Creek in the watershed plan, however the 10-year level of protection has been assigned to Reach 14. Other design considerations for Reach 14 were, the removal of the maintenance roads within the channel from the NRCS design, the addition of a fish barrier to preclude the steelhead from straying into East Little Llagas Creek, improved habitat for resident species, removal of four grouted rock drops from the NRCS design, maintaining the existing trail along the top of bank and improved channel stability. HEC-RAS was used to determine the water surface profiles for subcritical flow; the water surface profile for Reach 14 is shown on Plates 33.

The improvements to Reach 14 consist of deepening and widening of the channel. The channel widening was not limited to single bank modification method, as in Reaches 4, 5 and 6. The existing habitat is considered to be of relatively low value. The channel configuration throughout this section of Reaches 14 is dependent on the existing SCVWD right-of-way and channel gradient. The proposed design consists of a trapezoidal cross section. Maintenance access would be along the top of bank and would include maintaining the existing trail located on the top of the right bank, from the confluence with Llagas Creek to Sycamore Avenue. A plot of velocities in Reach 14 is shown on Plate 34.

From the confluence to the fish barrier at Station 10+00, the proposed trapezoidal cross section has a 50-ft bottom width, 1V:3H side slopes and a 14-ft depth. The design of the trapezoidal cross section assumes a Manning n-value of 0.05. The average channel velocities for this section of Reach 14 are 3.3 feet per second.

A 5- ft high vertical V-notch concrete drop structure, will be located in the diversion channel 1000-ft upstream from the confluence, at Station 10+00. The drop structure will help to prevent fish from straying into East Little Llagas Creek during low flows and the V-notch will allow out migration of errant fish that are able to migrate up East Little Llagas Creek. To create an undesirable condition for migrating steelhead, a concrete apron is to be placed upstream and downstream of the vertical drop, to prevent the erosion of the channel upstream of the drop and to prevent the creation of a pool below the drop. A schematic of the fish barrier in Reach 7a is shown on Plate 18.

From the fish barrier to Station 124+00, at Sycamore Avenue, the proposed trapezoidal channel continues, with a 50-ft bottom width, 1V:3H side slopes and 11-ft depth. The design of the trapezoidal cross section assumes a Manning n-value of 0.05. The average channel velocities for this section of Reach 14 are 5.0 feet per second.

Upstream of Sycamore Avenue, East Little Llagas Creek runs parallel to Hwy 101 from to Middle Avenue. Highway 101 in this area is located atop an embankment, which also acts as the right bank of East Little Llagas Creek. To avoid heavy modification to the Hwy 101 embankment, the proposed channel consists of a trapezoidal channel with a varying bottom width 15-ft to 40-ft, 1V:3H side slopes which tie into the existing embankment. Because the channel was relocated in the 1970's the existing channel was created with the use of levees on the left bank from station 131+00 to 144+00. To avoid drastic modification of the existing levees and the embankment, the bottom channel bottom width with only increase 5-ft, from 15-ft to 20-ft. However due to the increase peak flow in this area, the levees will need to continued down to Sycamore Avenue from station 131+00 to station 124+50. The design of the trapezoidal cross section assumes a Manning n-value of 0.05. The average channel velocities for this section of Reach 14 are 4.0 feet per second.

Upstream of Middle Avenue to the confluence with West Little Llagas Creek the proposed channel configuration has a 40-ft bottom width, 1V:3H side slopes and 7-ft depth. West Little Llagas Creek enters East Little Llagas Creek via a culvert under Hwy 101. The design of the trapezoidal cross section assumes a Manning n-value of 0.05. The average channel velocities for this section of Reach 14 are 4.0 feet per second.

At several locations within Reach 14, the design water surface elevation is above natural ground at several locations. However, the SVCWD freeboard requirement, Policy 3-218, does not apply when providing protection for the 10 percent flow. However, a minimum of one foot of freeboard will be used.

The NRCS design did not incorporate levees or berms on Reach 14. However, due to the updated hydrology, combined with backwater effects from Reach 4, levees or berms are necessary to contain the 10% flow. The locations where berms or

levees are necessary and the available freeboard at these problematic stations is shown in Table 23.

Table 23
Reach 14 – East Little Llagas Creek
Available Freeboard

River Sta	W.S. Elev (ft)	E.G. Elev (ft)	Available L. Freeboard (ft)	Available R. Freeboard (ft)	River Sta	W.S. Elev (ft)	E.G. Elev (ft)	Available L. Freeboard (ft)	Available R. Freeboard (ft)
13000.00	292.14	292.38	0.04	-0.44	9500.00	278.91	279.36	-0.68	1.48
12900.00	291.95	292.19	-2.01	-0.35	9400.00	278.55	279	-0.45	1.68
12800.00	291.81	292.02	-2.14	-1.65	9300.00	278.19	278.64	-0.16	1.29
12700.00	291.66	291.87	-1.43	-2.26	9200.00	277.83	278.28	0.17	1.17
12600.00	291.52	291.72	-1.46	-1.46	9100.00	277.47	277.92	0.53	-0.3
12570.00	291.48	291.67	-1.48	-1.47	9000.00	277.12	277.57	-1	-0.04
12400.00	290.25	290.44	-0.92	0.65	8900.00	276.78	277.22	-1.25	-0.52
12300.00	290.12	290.28	-0.21	0.1	8800.00	276.43	276.87	-0.25	-0.32
12200.00	289.54	290	1.46	0.58	8700.00	276.07	276.51	0.31	0.19
					8600.00	275.71	276.15	1.84	-0.43
10600.00	283.15	283.6	-0.13	1.85	8500.00	275.35	275.79	2.77	-0.35
10500.00	282.8	283.24	-0.76	1.2					
10400.00	282.47	282.9	-1.44	0.67	2300.00	255.99	256.27	2.17	-0.4
10300.00	282.16	282.58	-1.16	-0.04	2200.00	255.87	256.12	2.51	-0.73
10200.00	281.87	282.27	-0.81	-0.86	2100.00	255.75	255.99	2.46	-0.19
10100.00	281.6	281.98	1.55	-0.58	2000.00	255.65	255.87	1.84	0.33
10000.00	281.33	281.7	2.69	-0.33	1900.00	255.55	255.76	-0.04	-0.12
9900.00	281.08	281.43	1.13	-0.08	1800.00	255.48	255.66	-0.07	-0.49
9850.00	280.96	281.3	0.17	-0.87	1700.00	255.41	255.58	-0.09	-1.16
					1600.00	255.36	255.51	-1.01	-1.36
9500.00	278.91	279.36	-0.68	1.48	1500.00	255.32	255.45	-0.32	-2.04
9400.00	278.55	279	-0.45	1.68	1400.00	255.29	255.4	-1.22	-1.67
9300.00	278.19	278.64	-0.16	1.29	1300.00	255.26	255.36	-0.85	-2.06
9200.00	277.83	278.28	0.17	1.17	1200.00	255.23	255.32	-1.19	-1.88
9100.00	277.47	277.92	0.53	-0.3	1100.00	255.21	255.28	-1.98	-2.14
9000.00	277.12	277.57	-1	-0.04	1000.00	255.18	255.25	-2.35	-2.78
8900.00	276.78	277.22	-1.25	-0.52	900.00	254.07	254.42	-1.43	-1.88
8800.00	276.43	276.87	-0.25	-0.32	800.00	253.69	253.9	-1.69	-1.99
8700.00	276.07	276.51	0.31	0.19	700.00	253.07	253.22	-1.65	-1.99
8600.00	275.71	276.15	1.84	-0.43					
8500.00	275.35	275.79	2.77	-0.35					

There are four existing culverts within Reach 14, Church Avenue, San Martin Avenue, Sycamore Avenue and Middle Avenue. The existing culverts are capable of

conveying the design flood event, the 10% flood. The Reach 14 existing culvert information is included in Table 24.

Table 24
Reach 14 – East Little Llagas Creek
Existing Culverts

Reach 7 Location	Type of X-ing	Roadway Width (ft)	Culvert Description	
			No.	Culvert Size w(ft) x f(ft
Church Avenue	RCB	42	4	12 x 10
San Martin Avenue	RCB	41.5	4	12 x 7
Sycamore Avenue	RCB	60	3	11.5 x 7
Middle Avenue	RCB	163	3	10 x 9

The channel design summary table and various calculations for the proposed design are included in Appendix A. The HEC-RAS summary output and cross-section plots for East Little Llagas Creek are included in Appendix E

5.3.5 Reach 14 Channel Stability

An integrated approach to bank stabilization for the proposed design will be employed, including the addition of native vegetation, vegetated rip-rap and bank shaping within Reach 14. An additional benefit from incorporating vegetative methods includes the creation of potential wildlife habitat while providing bank and toe stabilization.

The proposed modifications to Reach 14 consist of deepening, widening and bank shaping, consisting of a trapezoidal cross section. The design in Reach 14 assumes a Manning n-value of 0.05 within the trapezoidal channel. A Manning's n-value of 0.05 allows for a medium amount of brushy, moderately dense vegetation along the banks and no significant amount of vegetation along the channel bottom.

The modified banks will be reshaped to provide a stable streambank with finished side slopes of 1V:3H or greater and replanted with native vegetation. Since the exposed streambank along the straight sections of the modified banks are susceptible to high flows prior to vegetation, appropriate vegetative streambank stabilization methods should be evaluated for suitability to the project. Vegetative stream bank stabilization methods such as brush mattresses, vegetated geogrids, vegetated rip-rap and other measures are possible effective bank stabilization techniques. Vegetated rip-rap, a typical section shown on Plate 21a, is flexible and not impaired by slight movement from settlement and where appropriate should be used to provide toe and

bank protection. Brush mattresses would provide an immediate protective cover and aid in the restoration of riparian vegetation and streamside habitat. A typical brush mattress schematic is shown on Plate 21b, Figure 1.

Essentially East Little Llagas Creek is a straight man-made channel, there are only 2 changes in direction for 3.4 miles of stream in Reach 14. The bends are located just upstream and downstream of Sycamore Avenue. Additionally, there are three major tributaries within the project area of Reach 14, Corralitos Creek, San Martin Creek and Church Creek. The vegetated riprap technique should be used to provide bank and toe protection of the outside bank at the bends and at the opposite bank of the tributary. Shown in Table 25 are the locations, length of section and the type of protection to be installed along the meander bend.

Table 25
Reach 14 East Little Llagas Creek
Streambank Protection

No.	Location	Left Bank (feet)	Right Bank (feet)	Type*
1	131+00 – 129+00		200	VRR
2	123+00 – 122+00	100		VRR
3	122+00 –119+00 (Corrolitos Ck)		300	VRR
4	65+00 – 64+00 (San Martin Ck)		100	VRR
5	5+00 –4+00 (Church Ck)		100	VRR
R14 Total length of Streambank Protection		*100*	*700*	

*Type of streambank protection to be used at that location, Vegetated Rip-Rap (VRR).

It appears that the lower portion of East Little Llagas Creek consists of a more gravel stream, while the upper protion consists of a earthen channel, therefore the more conservative mean channel velocity is used as a guide in determining the scour potential. The suggested maximum permissible mean channel velocities for grass lined earth; with slopes less than 5% is 5.0 feet per second. The maximum and minimum channel velocities in Reach 14 are 2.9 to 5.6 feet per second, respectively. The mean channel velocity of Reach 14 is 4.7 feet per second, well within the maximum permissible mean. A plot of the velocities in Reach 14 is included in Plate 34. Without further sediment transport analysis, based on maximum permissible velocities, under design conditions, East Little Llagas Creek along Reach 14 should be fairly resistant to scour.

6.0 HYDRAULIC ANALYSIS FOR LLAGAS CREEK AROUND LAKE SILVEIRA

The design objective for Llagas Creek, upstream of the Diversion Channel, is to reestablish the natural flow of Llagas Creek around Silveira Lake. HEC-RAS was used to determine the water surface profiles for subcritical flow.

Since completion of the NRCS design of the project, Llagas Creek approximately 1000-ft upstream of the diversion channel had been redirected to flow through Silveira Lake. Silveira Lake was an abandoned quarry site that was formed by diverting Llagas Creek through the quarry. At some time in the past 10 –15 years, an unknown party removed approximately 400-lft of earth through high ground to connect the Lake with Creek. In doing so, 1000-ft of Llagas Creek has been abandoned and left dry, year round. To reconnect Llagas Creek upstream of Silveira Lake with the natural channel, the Silveira Lake inlet channel should be filled and removed from the Llagas Creek system. The Silveira Lake outlet, approximately 800-ft downstream from the West Little Llagas Creek diversion channel, would remain, to allow water to enter the Lake from back-water from Llagas Creek during larger flows.

Llagas Creek around Silveira Lake consists of 0.29 miles (1,550 feet) of a levee on the left overbank, looking downstream, from Olive Avenue to the West Little Llagas diversion channel. The levee will leave the existing channel undisturbed. The right overbank consists of naturally high ground, except at the Silveira Lake inlet channel, and eventually ties into Silveira Lake. A channel n-value of 0.07 and an overbank n-value of 0.05 was assumed for this area of Llagas Creek. The average channel velocities in area are 4.2 feet per second. A typical section is shown on Plate 36 .

The levee along the left overbank would tie into the diversion channel levee. The minimum freeboard varies from 3.5 to 2.0 feet, based the SVCWD freeboard requirements, Policy 3-218, A (1), where the design water surface elevation is above natural ground and below natural ground. The levee will provide maintenance access to the area and consists of 1V:2H side slopes with a 12 ft top width, varying from 5 – 6 feet in height. The levee will provide protection against the 100-year flood, so that area north of the levee will not be prone to induced flooding from West Little Llagas Creek. The proposed freeboard requirements for this area of the project around Lake Silveira are shown in Table 26.

The West Little Llagas Creek Diversion Channel ties into the left Llagas Creek Levee upstream, around Lake Silveira. The levee around Lake Silveira consists of 1630-ft of earthen levee. The water surface profile for the entire length of Llagas Creek, from upstream of the Diversion Channel to Buena Vista Avenue, is shown on Plate 37.

The channel design summary for the proposed design for Llagas Creek around Lake Silveira have been summarized in Appendix A. The HEC-RAS summary output and cross-section plots for Llagas Creek are included in Appendix D.

Table 26
Llagas Creek Around Lake Silveira
Levee Freeboard

River Sta	Min Ch El (ft)	W.S. Elev (ft)	E.G. Elev (ft)	0.2EG Freeboard (ft)	Levee El Left (ft)	L. Levee Frbrd (ft)	L. Freeboard (ft)
1250	310	319.56	319.94	1.988	321.6	2.04	0.44
1150	308	318.93	319.23	2.246	321.3	2.37	0.07
1050	308	318.69	318.86	2.172	322.3	3.61	-0.69
940	308	318.58	318.7	2.14	322.2	3.62	-0.58
845	308	318.48	318.59	2.118	322.1	3.62	-0.48
700	307.97	318.27	318.4	2.086	321.9	3.63	-1.27
600	308	317.91	318.2	2.04	321.6	3.69	-0.91
500	307.57	317.24	317.74	2.034	321	3.76	-1.33
400	306	317.07	317.27	2.254	320.8	3.73	-1.07
300	306	316.88	317.04	2.208	320.7	3.82	-1.09
200	306	316.75	316.89	2.178	320.6	3.86	-1.85
90	305	316.33	316.66	2.332	320.2	3.87	-0.34
10	305	315.78	316.31	2.262	319.7	3.92	-0.78

draft

7.0 REFERENCES

1. U.S. Department of Agriculture, Soil Conservation Service, Llagas Creek, Hydraulic Design Report - Reaches 4,5, and 6, February 1994.

2. U.S. Department of Agriculture, Soil Conservation Service, Llagas Creek, Hydraulic Design Report - Reaches 7A and 7B, October 1993.

3. U.S. Department of Agriculture, Soil Conservation Service, Llagas Creek, Hydraulic Design Report – Reach 14, December 1994.

4. Santa Clara County, California, Upper Llagas Creek Watershed Work Plan, September 1967.

5. U.S. Army Corps of Engineers, San Francisco District, General Design Memorandum – Pajaro River Basin/Uvas-Carnadero Creek, July 1981.

6. U.S. Army Corps of Engineers, Hydrologic Investigation, Llagas Creek Flood Control Project, prepared by Abdallah D. Saah for the U.S. Army Corps of Engineers, San Francisco District, June 2001.

7. Chow, Open Channel Hydraulics. 1959

8. King, Handbook of Hydraulics

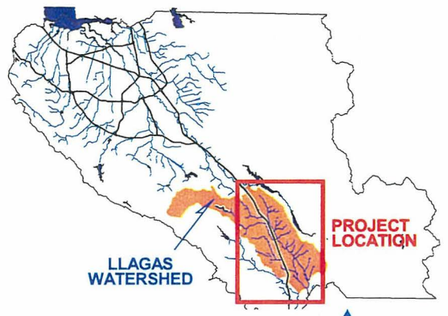
9. Department of the Interior, USGS Water Supply Paper 2339. 1992. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains.

10. U.S. Fish and Wildlife Service, Habitat Evaluation Prodedures (HEP) Application, for the Proposed Llagas Creek Flood Control Project – June 2002.

11. Federal Interagency Stream Restoration Working Group. 1992. Stream Corridor Restoration. Principles, Processes, and Practices.

Llagas Creek Flood Control Project

REACH 4 2.26 Miles
REACH 8 1.19 Miles
REACH 5 0.9 Miles
REACH 14 2.3 Miles
REACH 6 3.18 Miles
1% FLOOD-PLAIN
REACH 7 2.52 Miles
LLAGAS WATERSHED
CONSTRUCTION COMPLETED



Santa Clara Valley Water District
Geographic Information Systems

N
W E
S

TO BE RESTUDIED

EARTH CHANNEL

EARTH CHANNEL DIVERSION 5,000 LINEAR FT.

EARTH CHANNEL

EARTH CHANNEL

UPPER LLAGAS CREEK
LOWER LLAGAS CREEK

Cochran Channel
Madrone Channel
Anderson Reservoir
Tennant Creek
MORGAN HILL
West Little Llagas Creek
Chesbro Reservoir
Uvas Reservoir
Coyote Reservoir
Main Branch Llagas Creek
East Little Llagas Creek
West Branch Llagas Creek
GILROY
Llagas Creek
Uvas-Carnadero Creek
Pajaro River

COCHRAN RD
E MAIN AV
E DUNNE AV
WRIGHT AV
TENNANT AV
SPRR
MAPLE AV
LA CROSSE DR
WATSONVILLE RD
FOOTHILL AV
CENTER AV
COLUMBET AV
E SAN MARTIN AV
W SAN MARTIN AV
CHURCH AV
MASTEN AV
MONTEREY RD
BUENA VISTA AV
LEAVESLEY RD
FURGUSON RD
CANADA RD
BLOOMFIELD AV
101
152
152

REACH	FROM	TO
1	Pajaro River	Bloomfield Ave.
2	Bloomfield Ave.	700 ft. upstream of Hwy. 152
3	700 ft. upstream of Hwy. 152	Buena Vista Ave.
4	Buena Vista Ave.	East Little Llagas
5	East Little Llagas	700 ft. upstream of South Valley Fwy.
6a	700 ft. upstream of South Valley Fwy.	West Little Llagas Creek
7a	Main Branch Llagas Creek	La Crosse St.
7b	La Crosse St.	West Dunne Ave.
8a	West Dunne Ave.	Wright Ave.
8b	Wright Ave.	200 ft. upstream of Hale Ave.
14	Main Branch Llagas Creek	2400 ft. upstream of San Martin Ave.

PLATE 1

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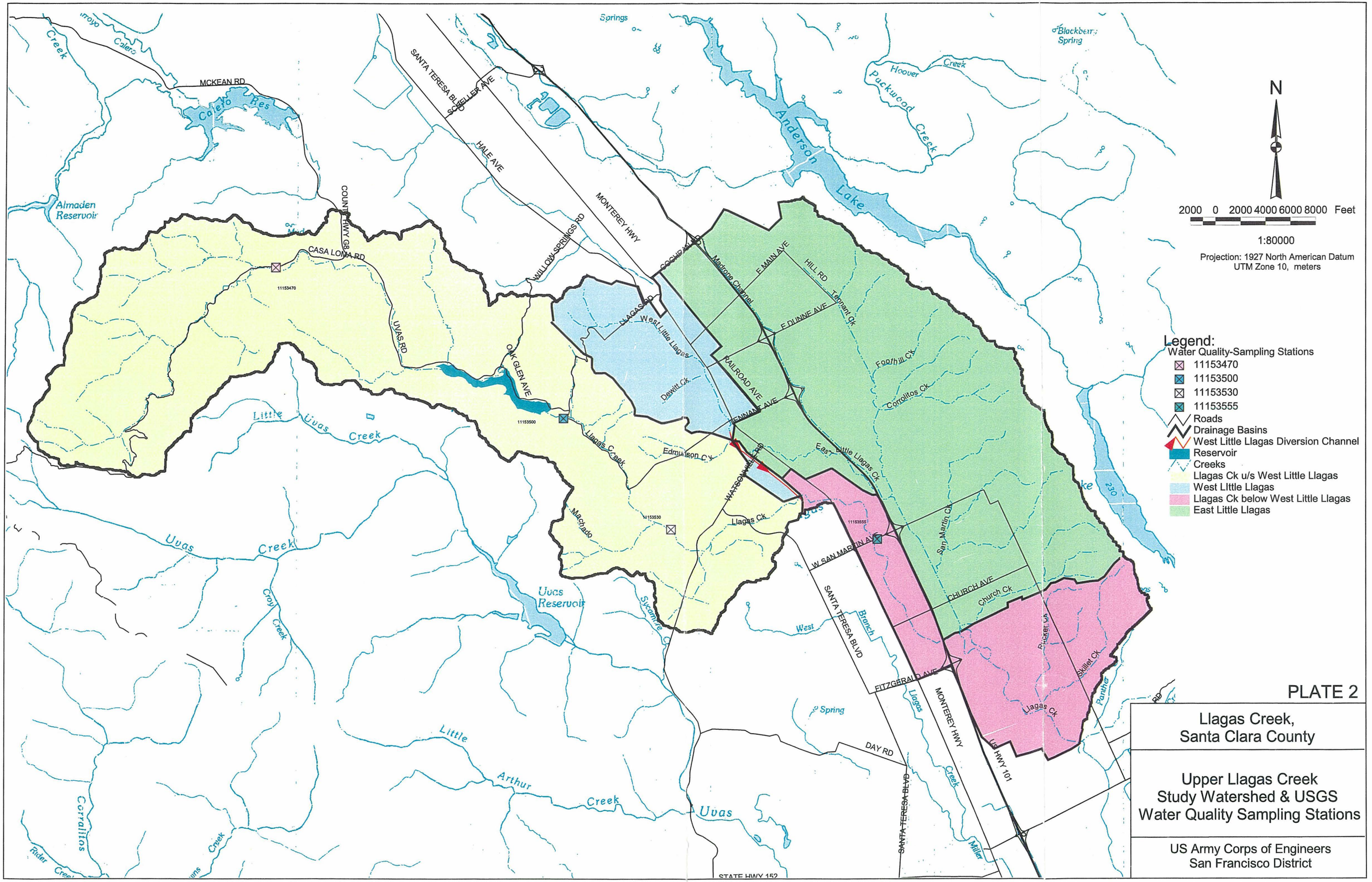
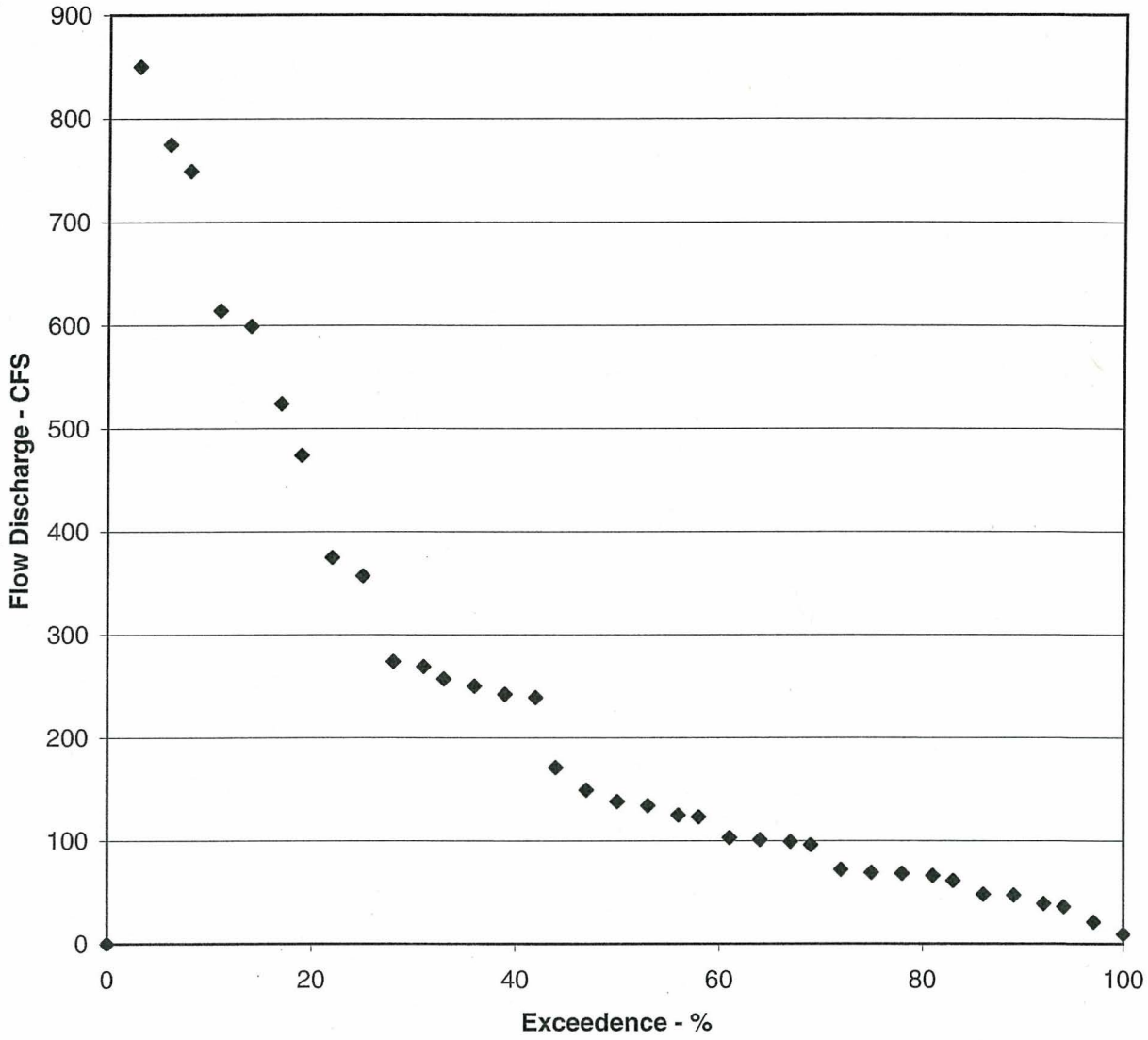


PLATE 2

Llagas Creek, Santa Clara County

Upper Llagas Creek Study Watershed & USGS Water Quality Sampling Stations

US Army Corps of Engineers
San Francisco District

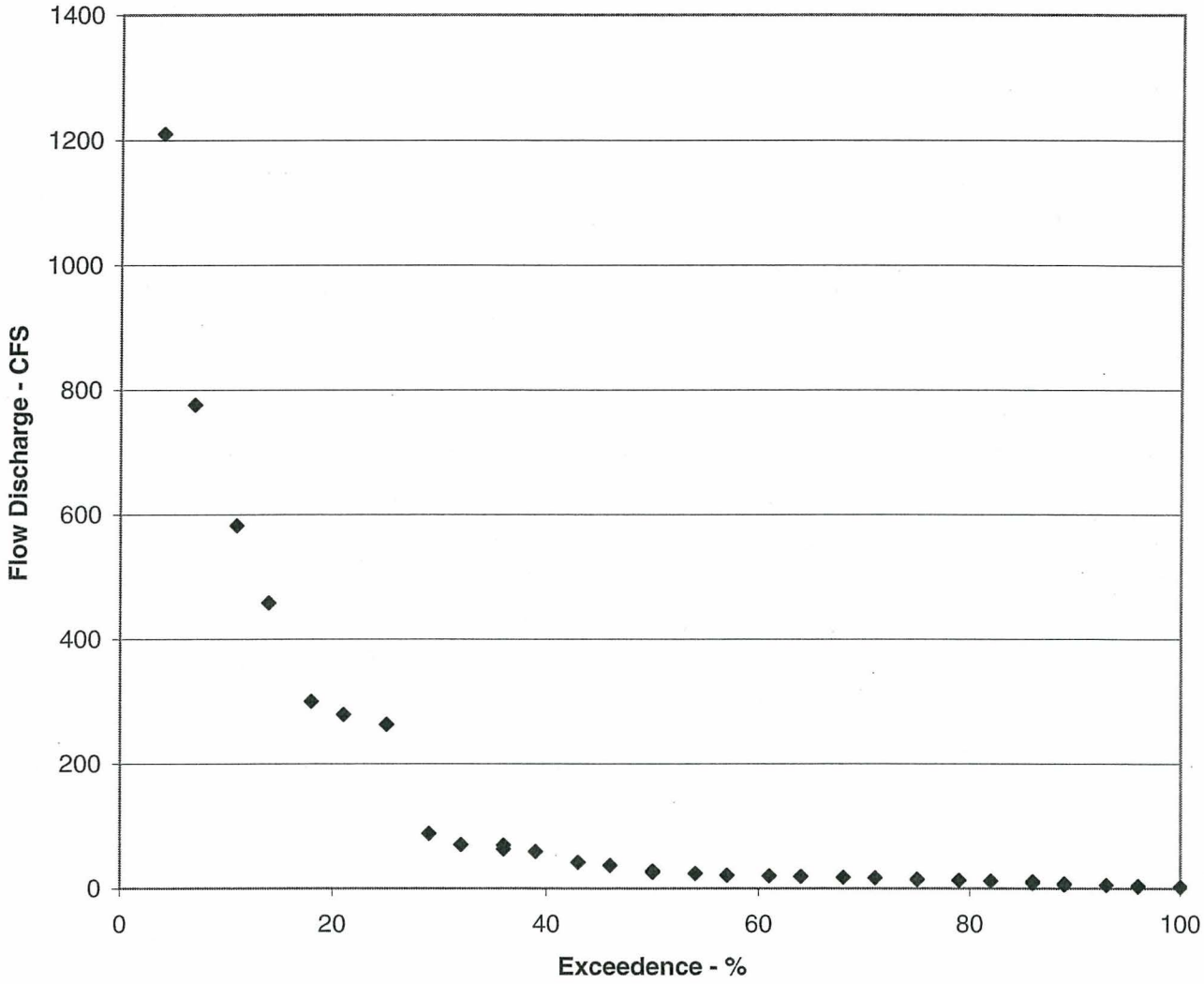


Llagas Creek Flood Control Project,
Santa Clara County

Llagas Creek
Flow Duration Curve
USGS Gage 11153470

US Army Corps of Engineers
San Francisco District

PLATE 3

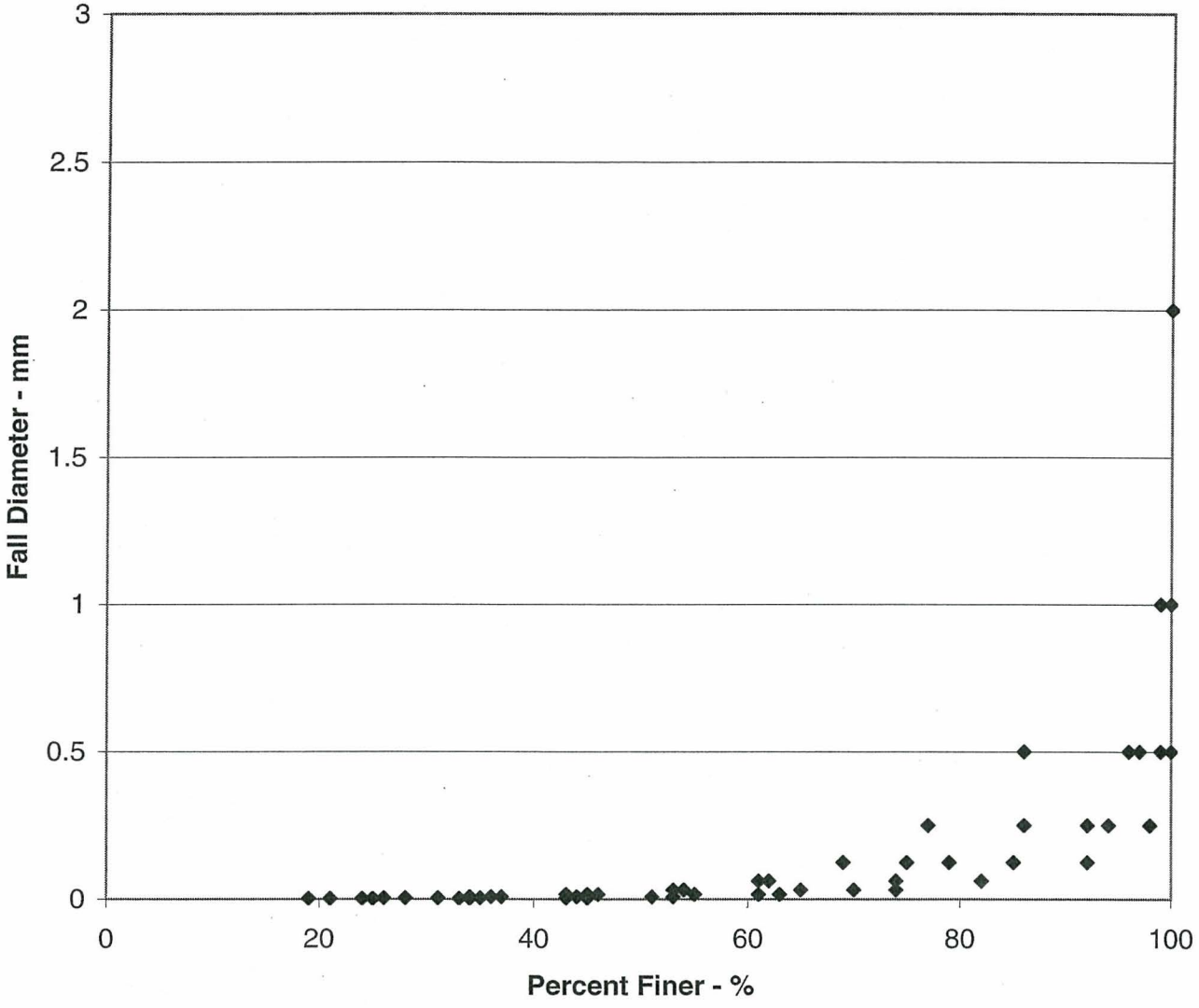


Llagas Creek Flood Control Project,
Santa Clara County

Llagas Creek
Flow Duration Curve
USGS Gage 11153555

US Army Corps of Engineers
San Francisco District

PLATE 4

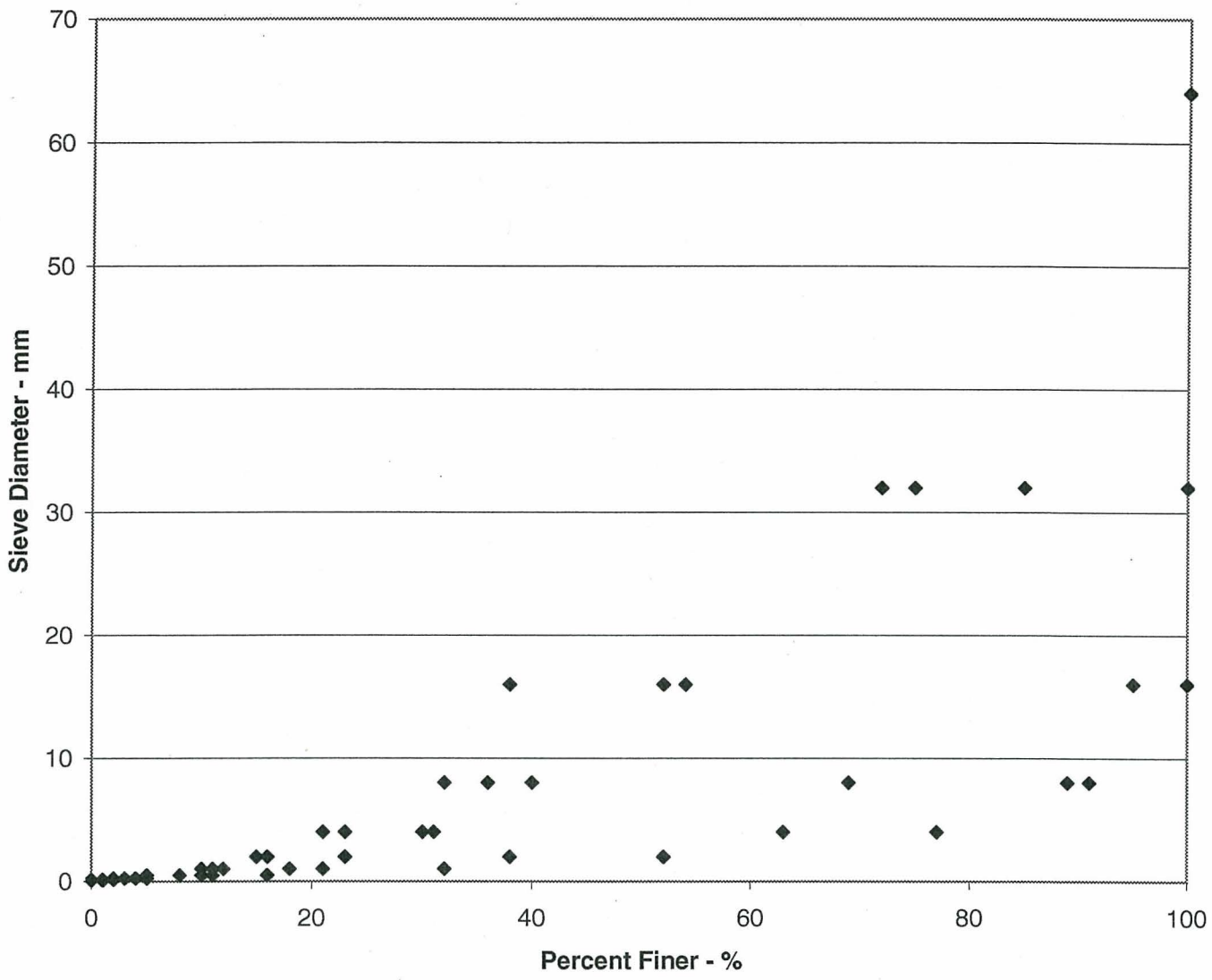


Llagas Creek Flood Control Project,
Santa Clara County

Llagas Creek
Suspended Sediment Fall Diameter, USGS Gage 11153470

US Army Corps of Engineers
San Francisco District

PLATE 5

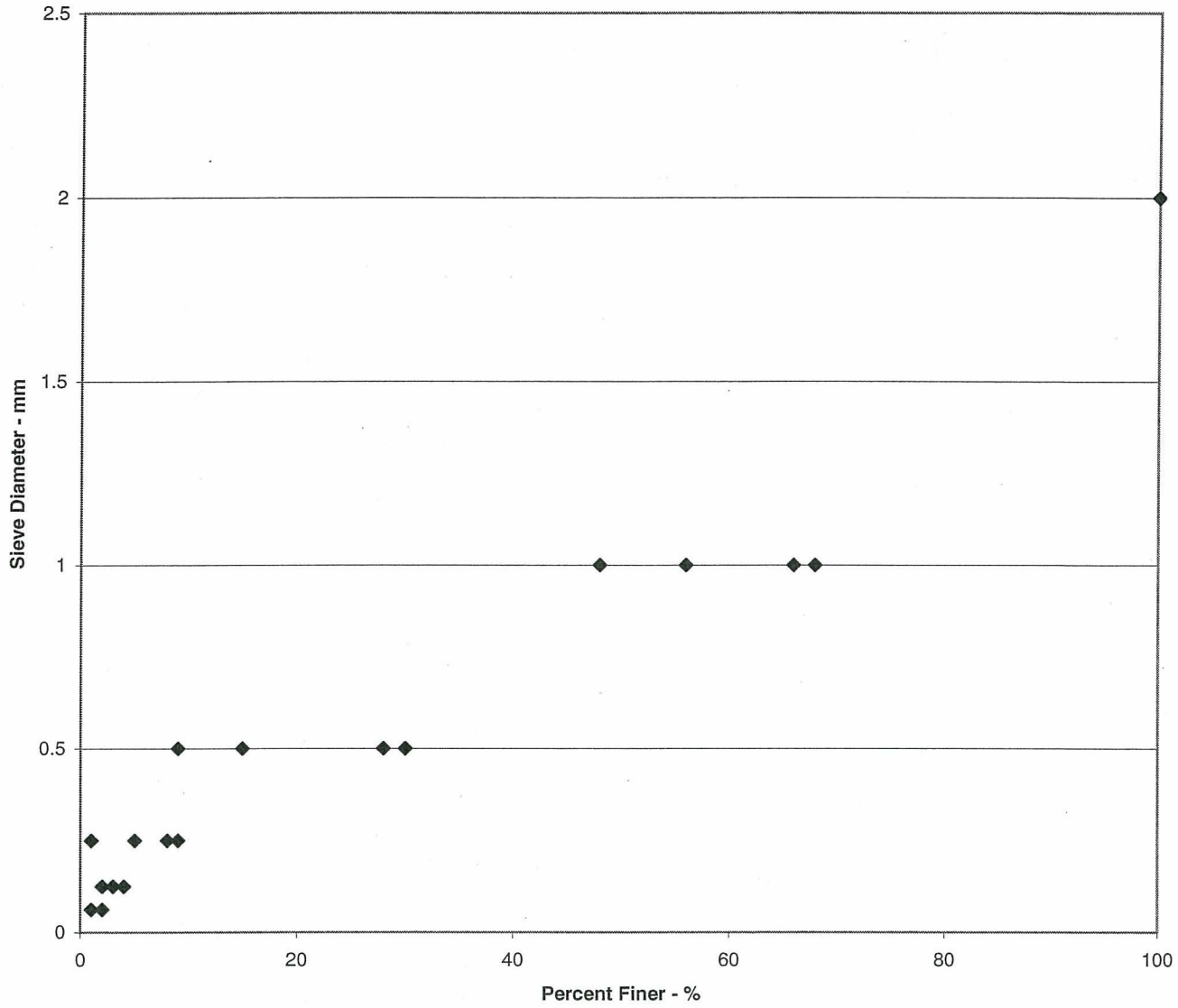


Llagas Creek Flood Control Project,
Santa Clara County

Llagas Creek
Bed-material Size Distribution,
USGS Gage 11153470

US Army Corps of Engineers
San Francisco District

PLATE 6

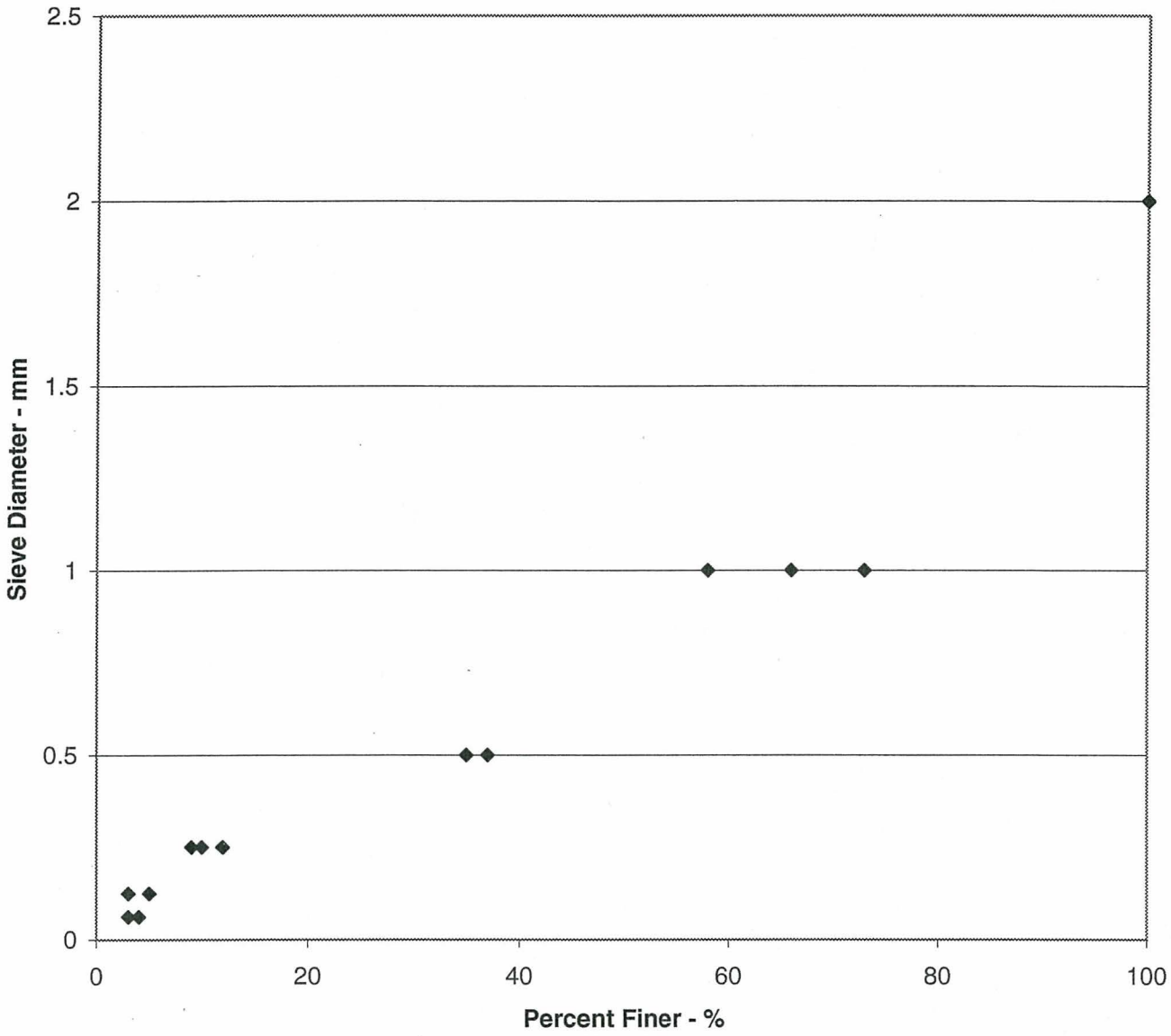


Llagas Creek Flood Control Project,
Santa Clara County

Llagas Creek
Bed-Material Size Distribution
USGS Gage 11153530

US Army Corps of Engineers
San Francisco District

PLATE 7

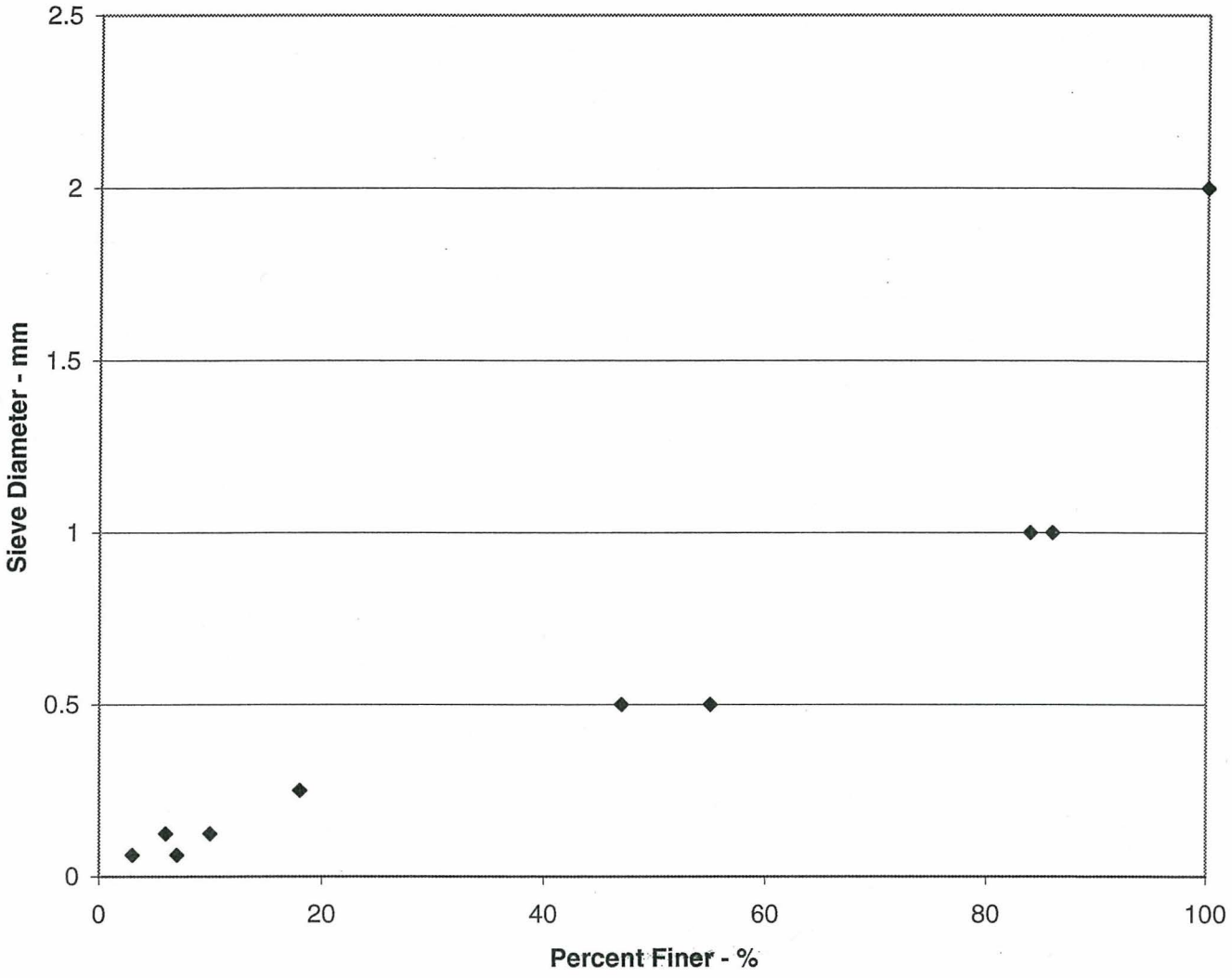


Llagas Creek Flood Control Project,
Santa Clara County

Llagas Creek
Bed-Material Size Distribution
USGS Gage 11153555

US Army Corps of Engineers
San Francisco District

PLATE 8

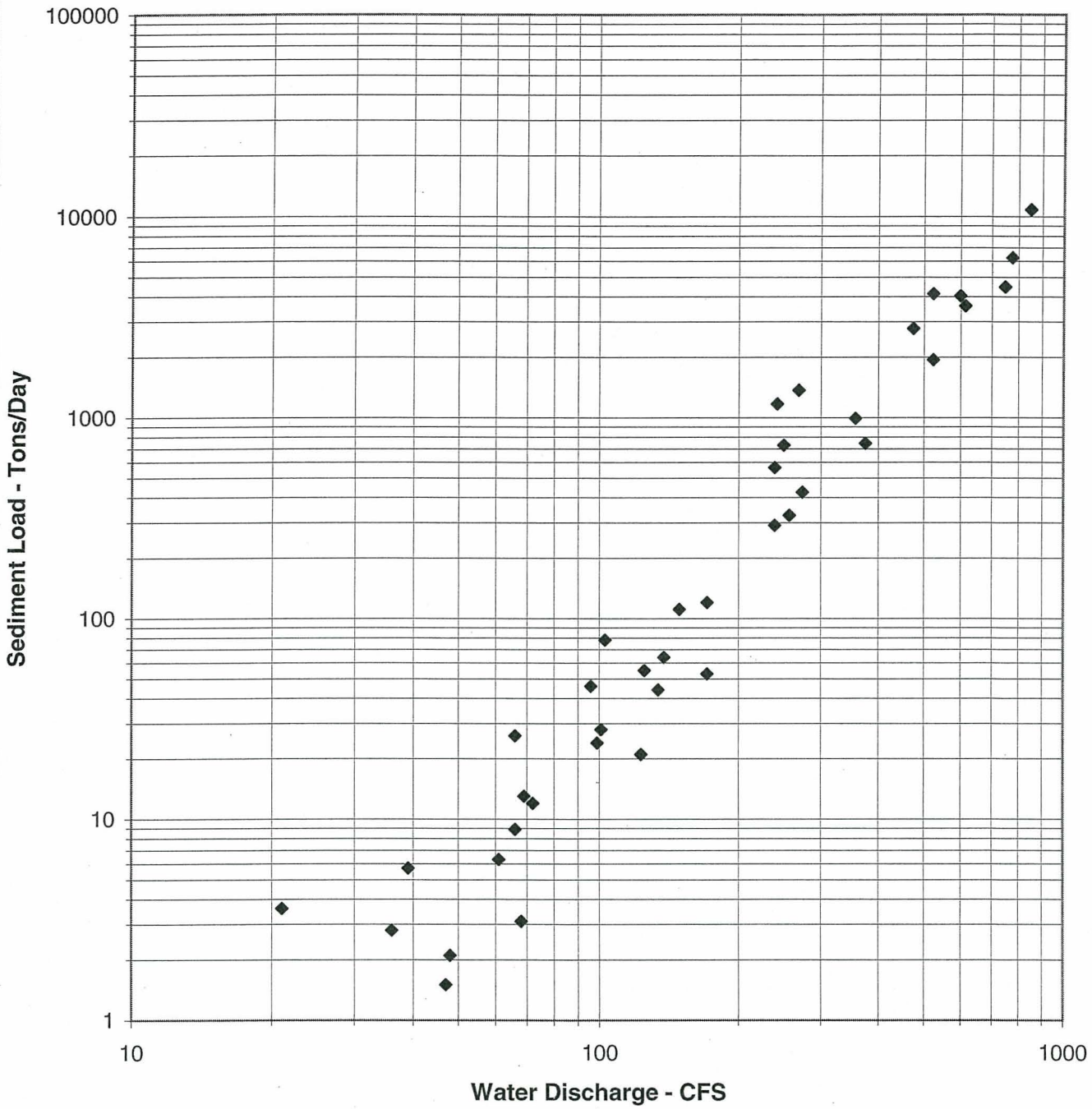


Llagas Creek Flood Control Project,
Santa Clara County

Llagas Creek
Bed-Material Size Distribution
USGS Gage 11153500

US Army Corps of Engineers
San Francisco District

PLATE 9



Llagas Creek Flood Control Project,
Santa Clara County

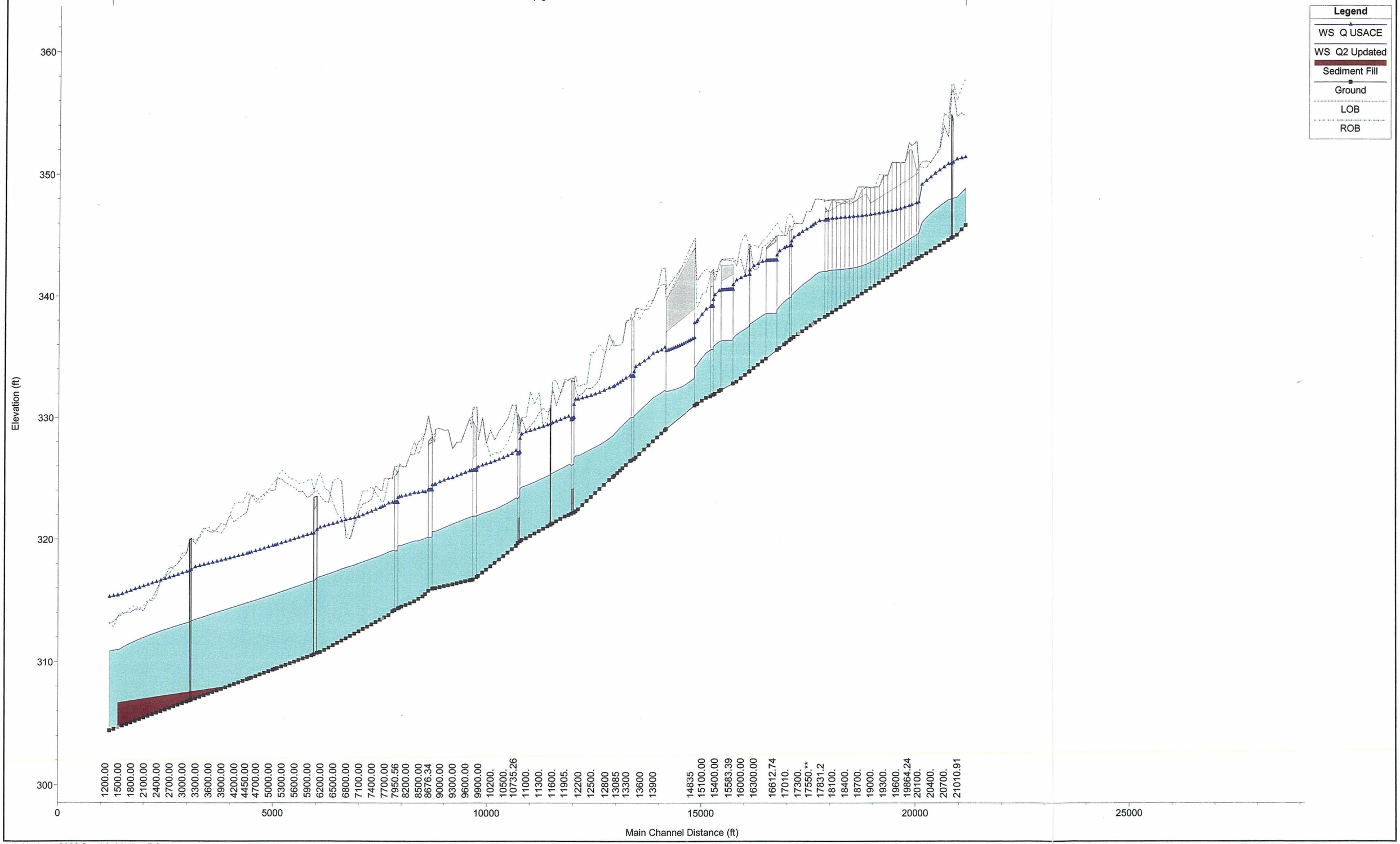
Llagas Creek, Sediment Discharge Rating Curve USGS Gage 11153530

US Army Corps of Engineers
San Francisco District

PLATE 10

LLagas Preliminary Design Plan: preliminary design

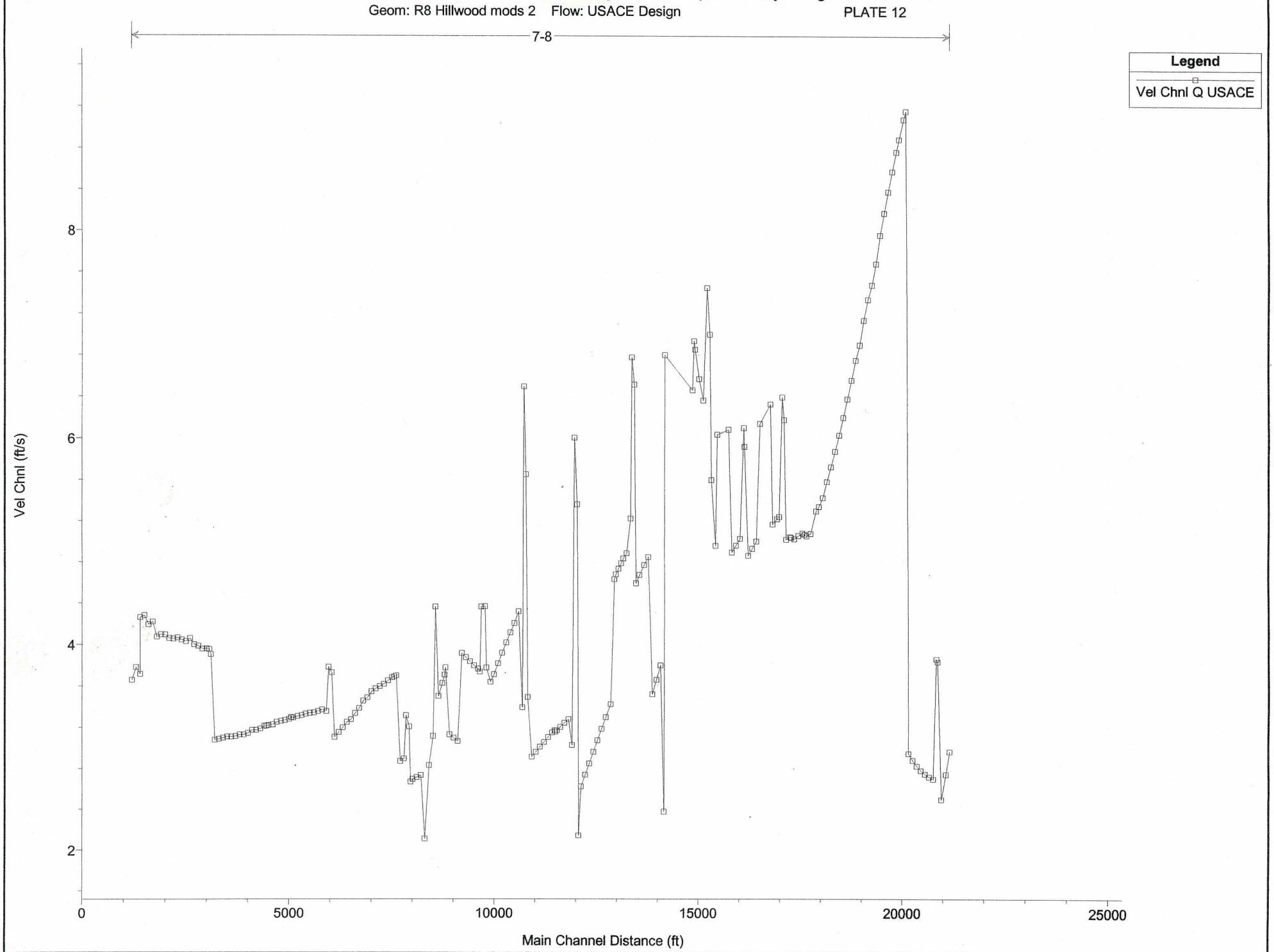
Geom: R8 Hillwood mods + R14 Flow: USACE Design PLATE 11



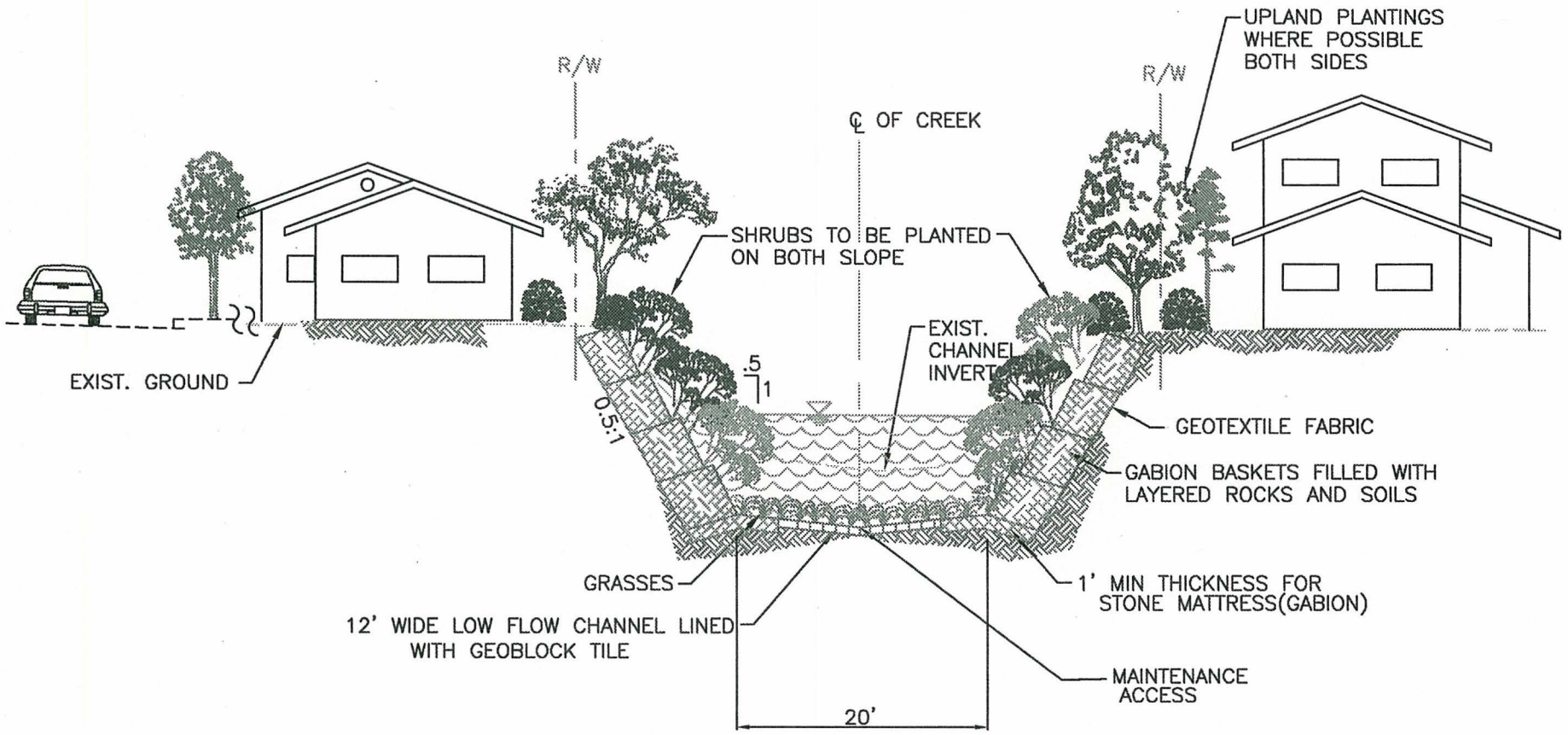
1 in Horiz. = 2000 ft 1 in Vert. = 7 ft

LLagas Preliminary Design Plan: preliminary design

Geom: R8 Hillwood mods 2 Flow: USACE Design PLATE 12



1 in Horiz. = 3000 ft 1 in Vert. = 1.2 ft/s



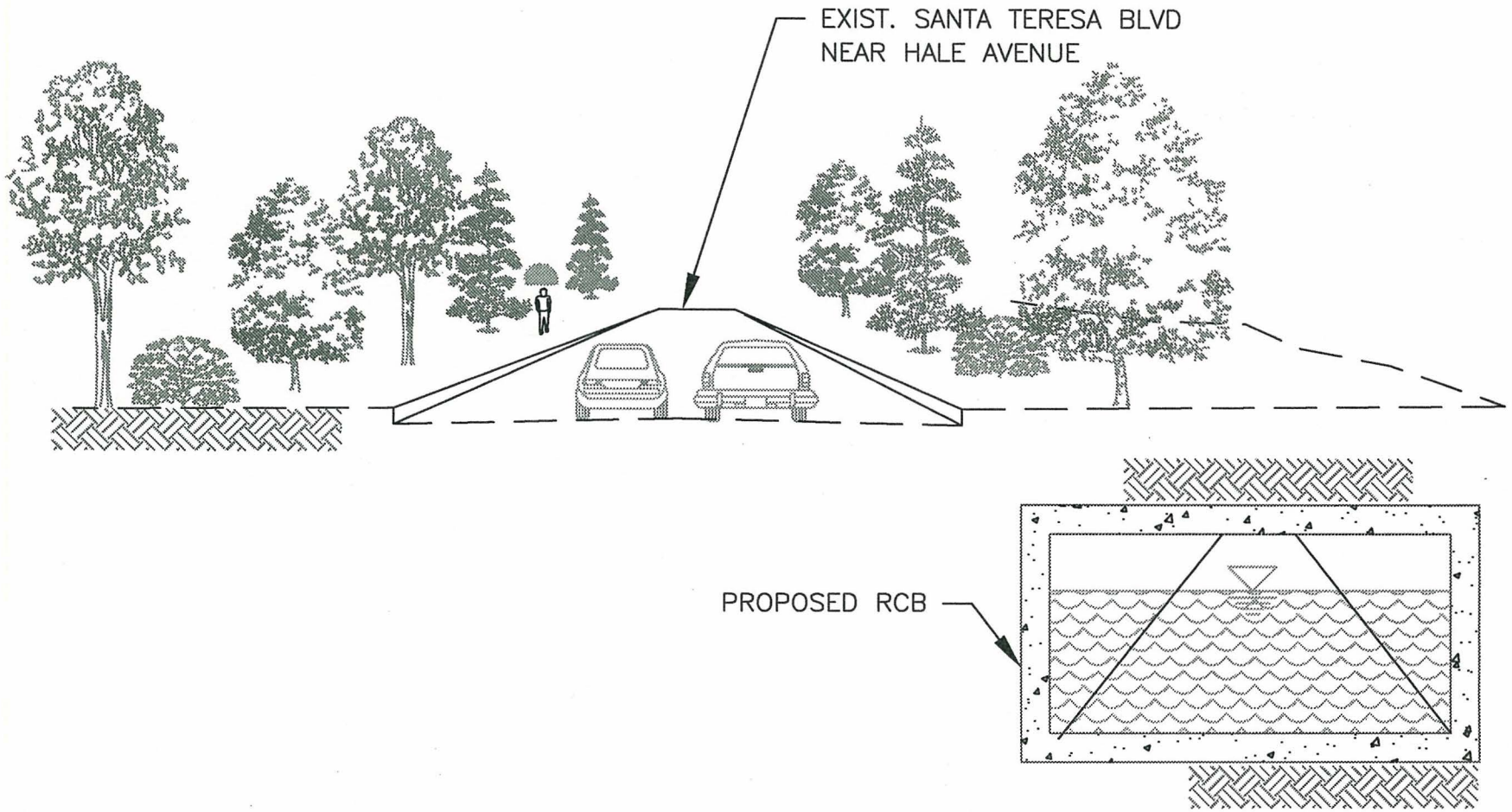
TYPICAL SECTION

LLAGAS CREEK REACH 8

MORGAN HILL (DOWNTOWN)
VEGETATED GABION ROCK LINING
2002 PLAN
NTS

PLATE 13

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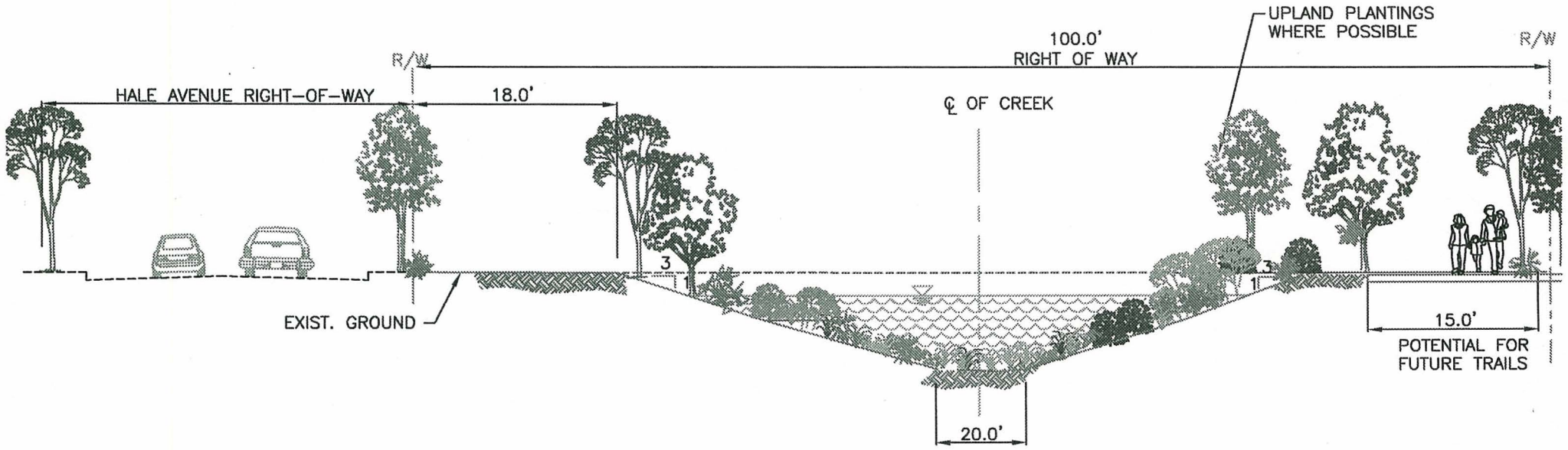
TYPICAL SECTION

LLAGAS CREEK REACH 8 (LOOKING UPSTREAM)
CONCRETE CULVERT
BETWEEN MAIN AND WRIGHT AVENUE
NTS

2002 PLAN

PLATE 14

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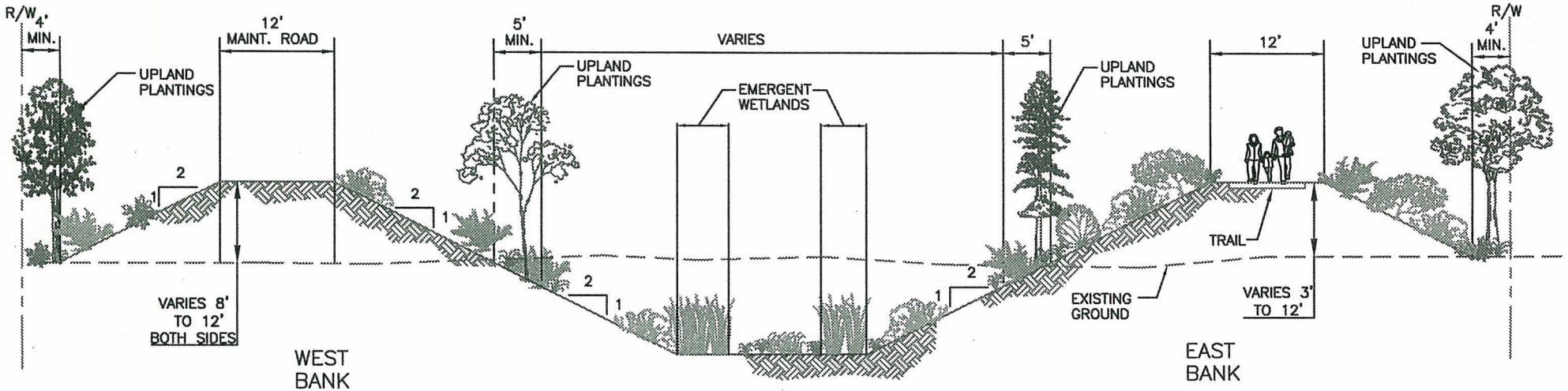
TYPICAL SECTION

LLAGAS CREEK REACH 8
MORGAN HILL(DOWNTOWN)
BETWEEN WRIGHT AVE. AND HILLWOOD LANE (END OF PROJECT)
LOOKING DOWNSTREAM
NTS

2002 PLAN

PLATE 15

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TYPICAL SECTION

WEST LITTLE LLAGAS CREEK REACH 7

FROM LLAGAS CK CONFLUENCE TO MIDDLE AVENUE

STATION 2000+00

DIVERSION CHANNEL

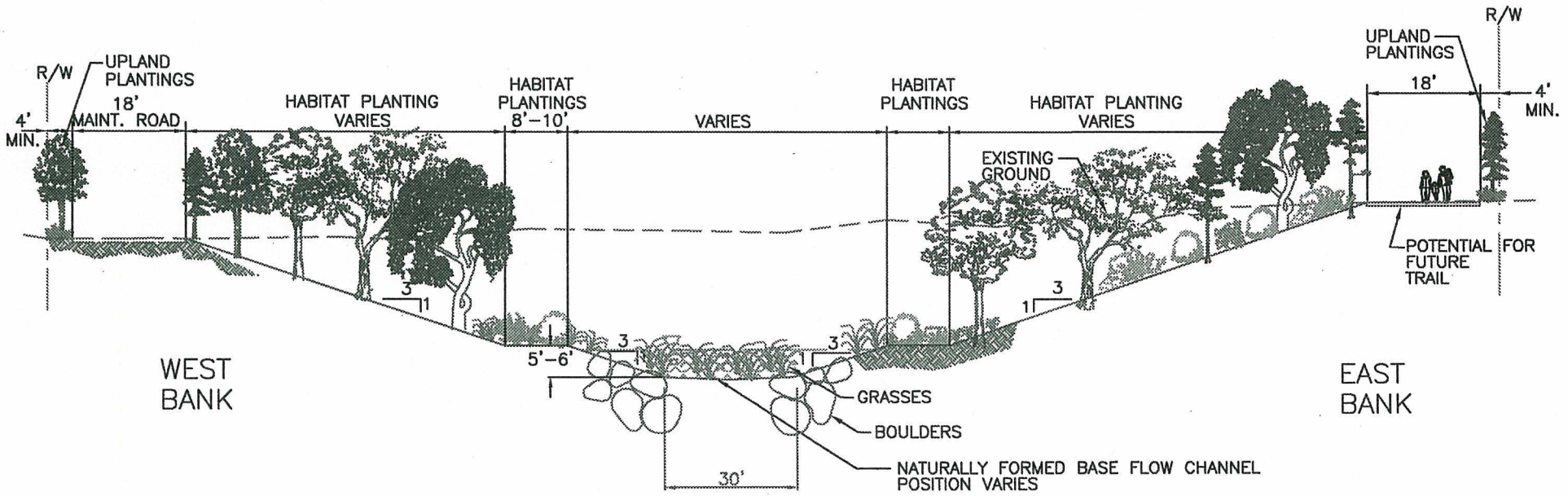
(LOOKING DOWNSTREAM)

NTS

2002 PLAN

PLATE 16

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TYPICAL SECTION

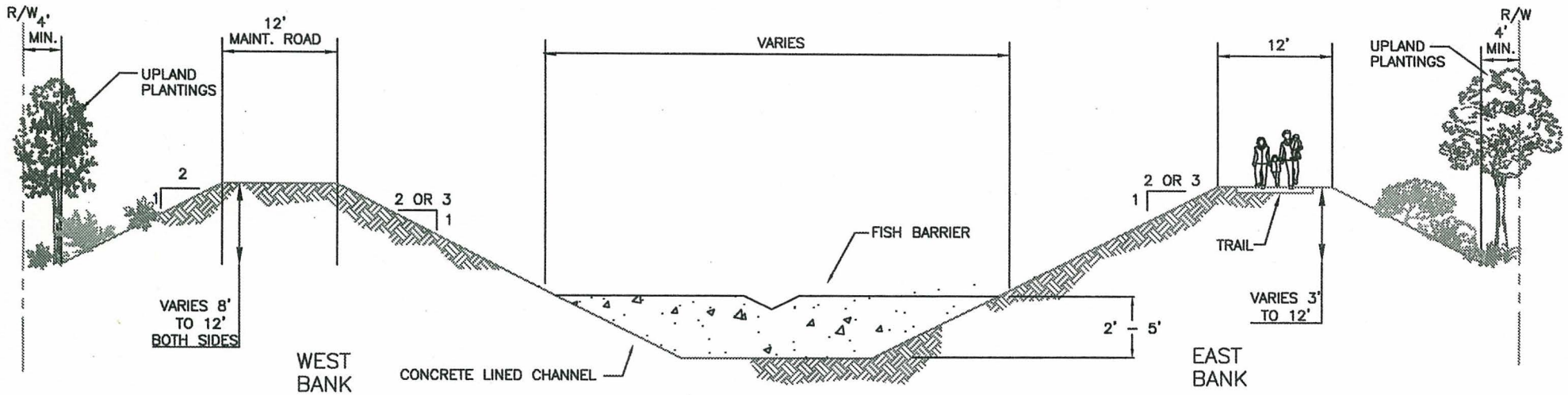
WEST LITTLE LLAGAS CREEK REACH 7

FROM MIDDLE AVENUE TO END OF DIVERSION
DIVERSION CHANNEL
STATION 5600+00
(LOOKING DOWNSTREAM)
NTS

2002 PLAN

PLATE 17

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH7d.dwg



TYPICAL SECTION

WEST LITTLE LLAGAS CREEK DIVERSION CHANNEL – REACH 7a STATION 14+00

AND EAST LITTLE LLAGAS CREEK – REACH 14 STATION 10+00

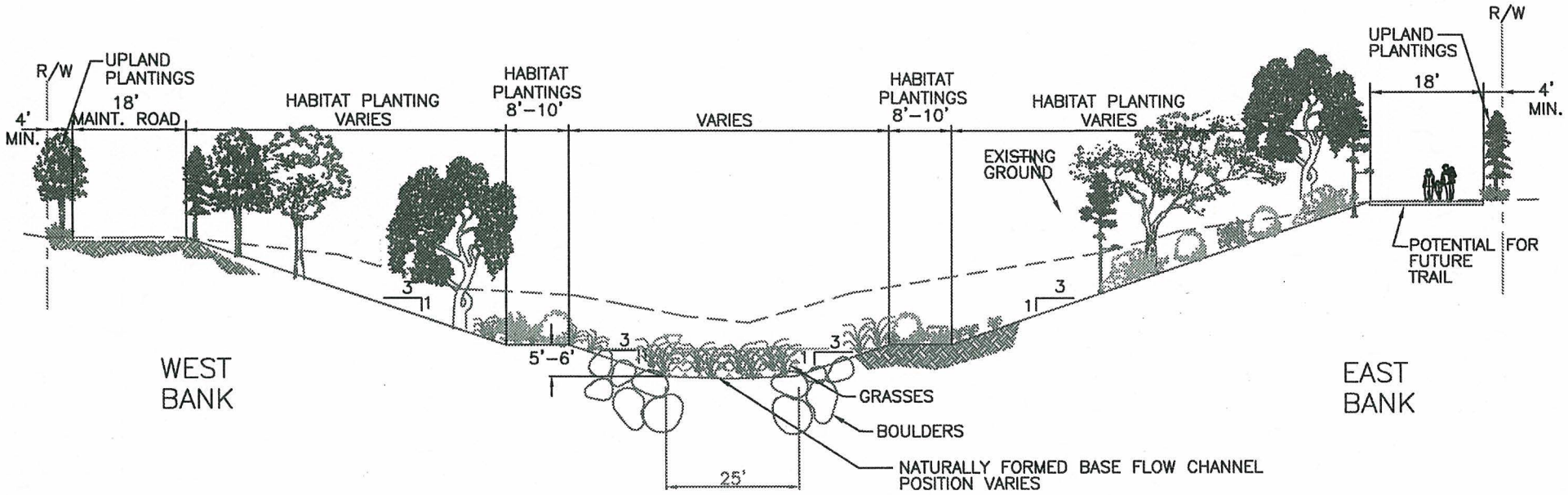
(LOOKING DOWNSTREAM)

NTS

2002 PLAN

PLATE 18

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH7c.dwg



TYPICAL SECTION

WEST LITTLE LLAGAS CREEK REACH 7b

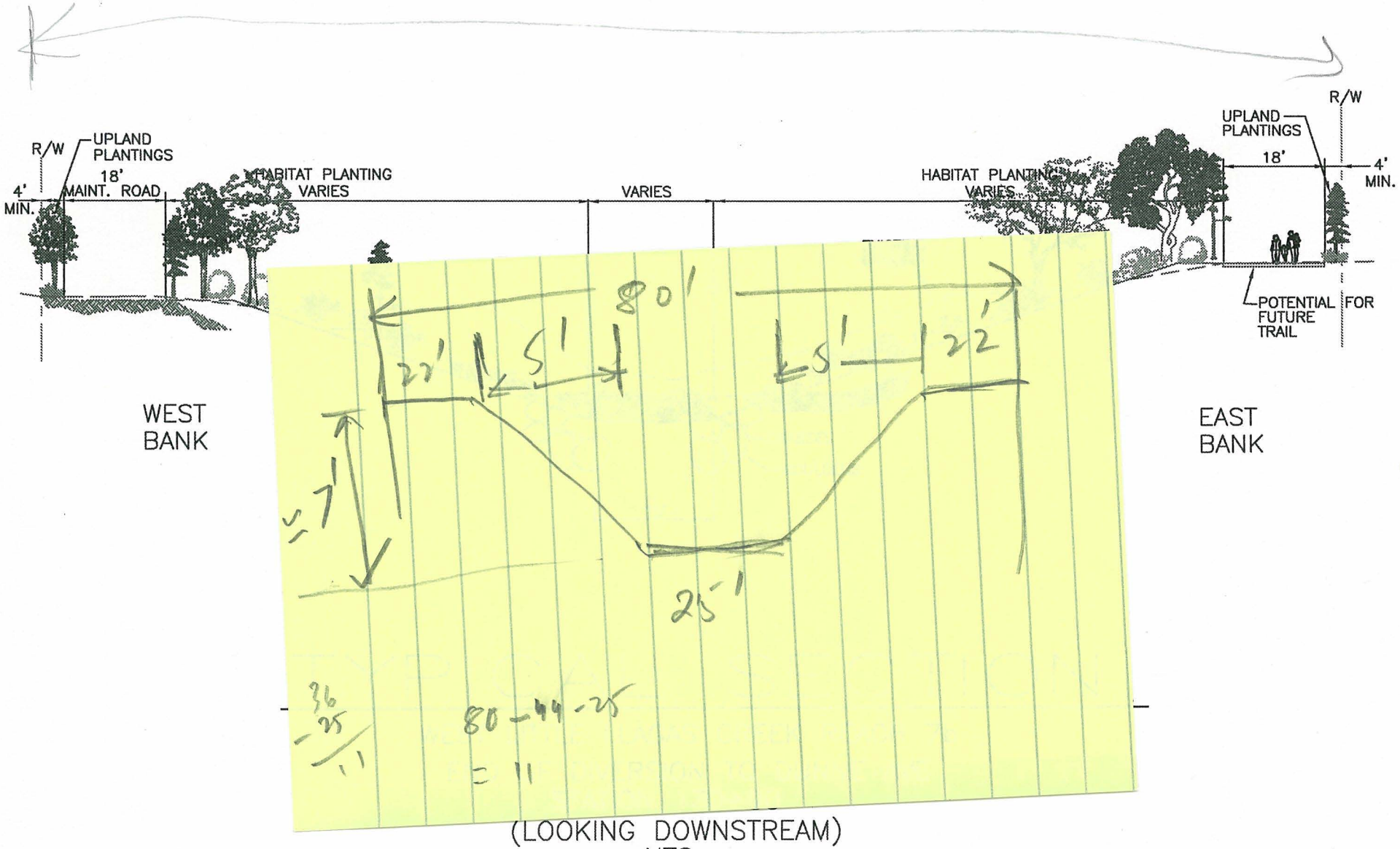
END OF DIVERSION TO DUNNE AVE

STATION 117+00
(LOOKING DOWNSTREAM)
NTS

2002 PLAN

PLATE 19

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH7d.dwg



(LOOKING DOWNSTREAM)
NTS

2002 PLAN

PLATE 20

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH7d.dwg

TYPICAL

VEGETATED RIP-RAP NTS

Llagas Creek Flood Control Project, Santa Clara County
Llagas Creek Proposed Bank Stabilization Features
US Army Corps of Engineers San Francisco District

PLATE 21a

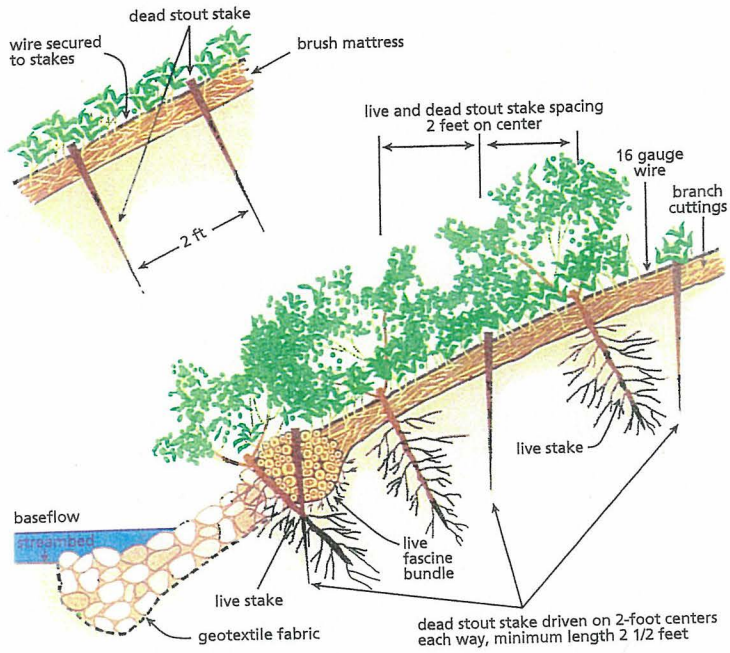


Figure 1.
Brush Mattress Typical
Source: USDA-NRCS 1996a

Note: Rooted/leafed condition of the living plant material is not representative at the time of installation

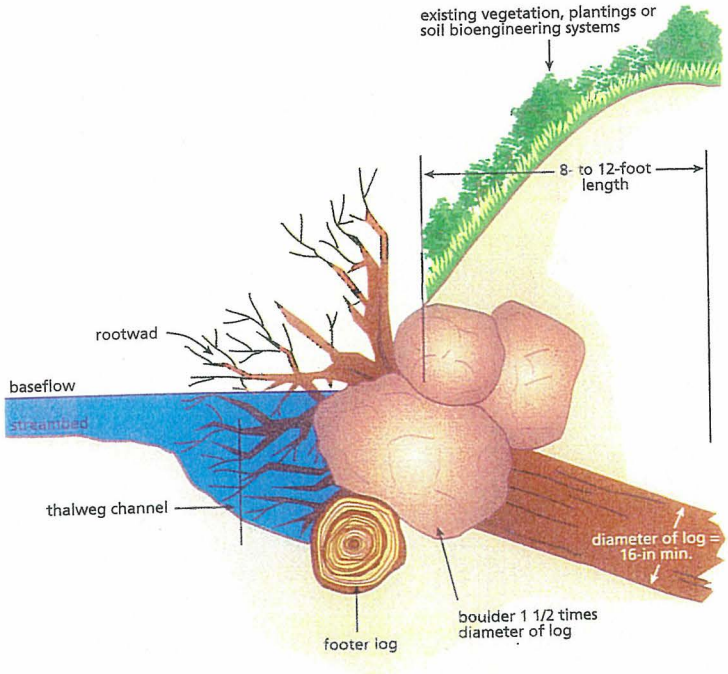
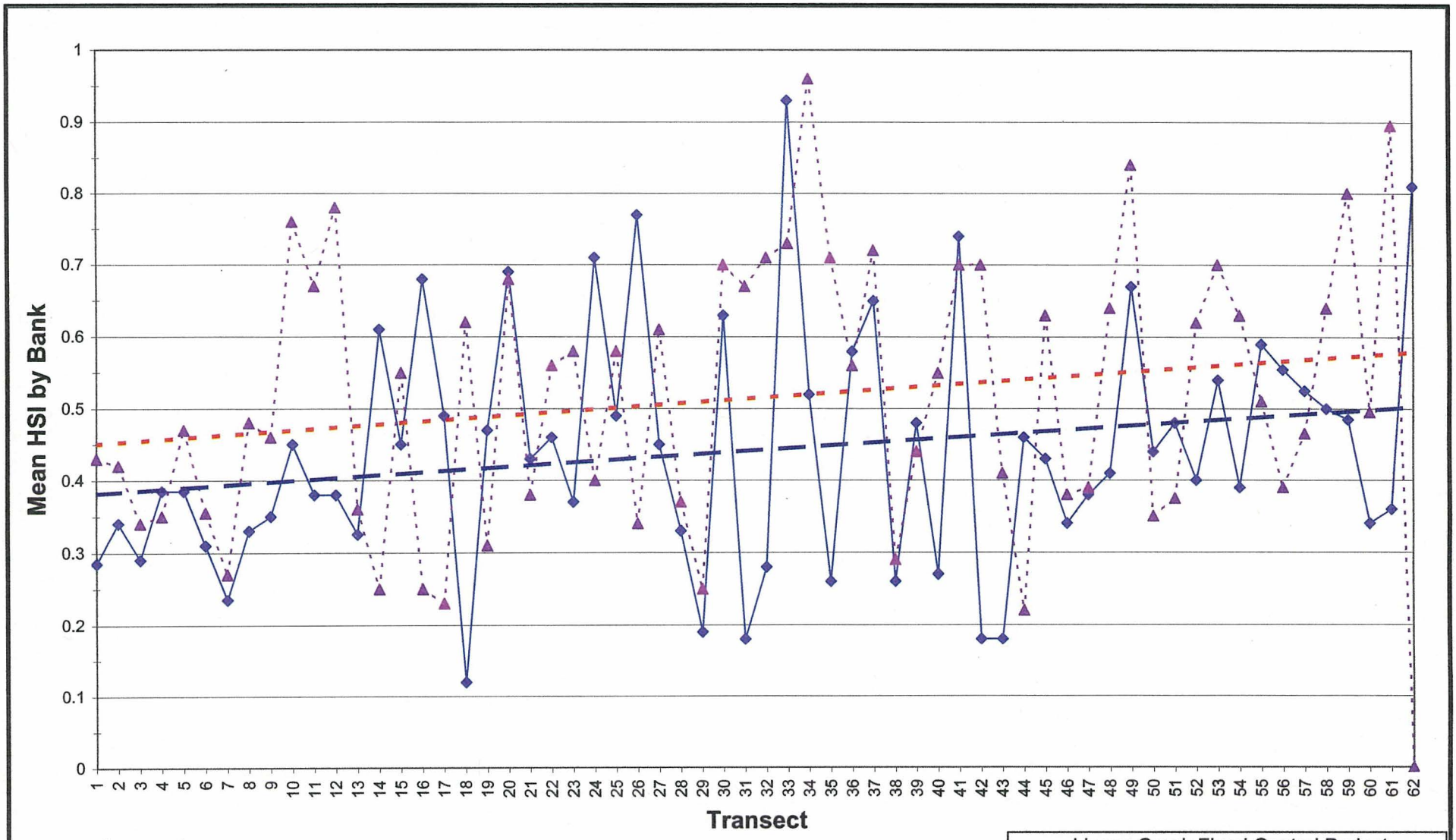


Figure 2.
Rootwad and Boulder Reventment System Typical Section
Source: USDA-NRCS 1996a

Llagas Creek Flood Control Project, Santa Clara County
Llagas Creek Proposed Bank Stabilization Features
US Army Corps of Engineers San Francisco District

PLATE 21b



Legend:

- Left Bank
- Right Bank
- Left Bank Trendline
- Right Bank Trendline

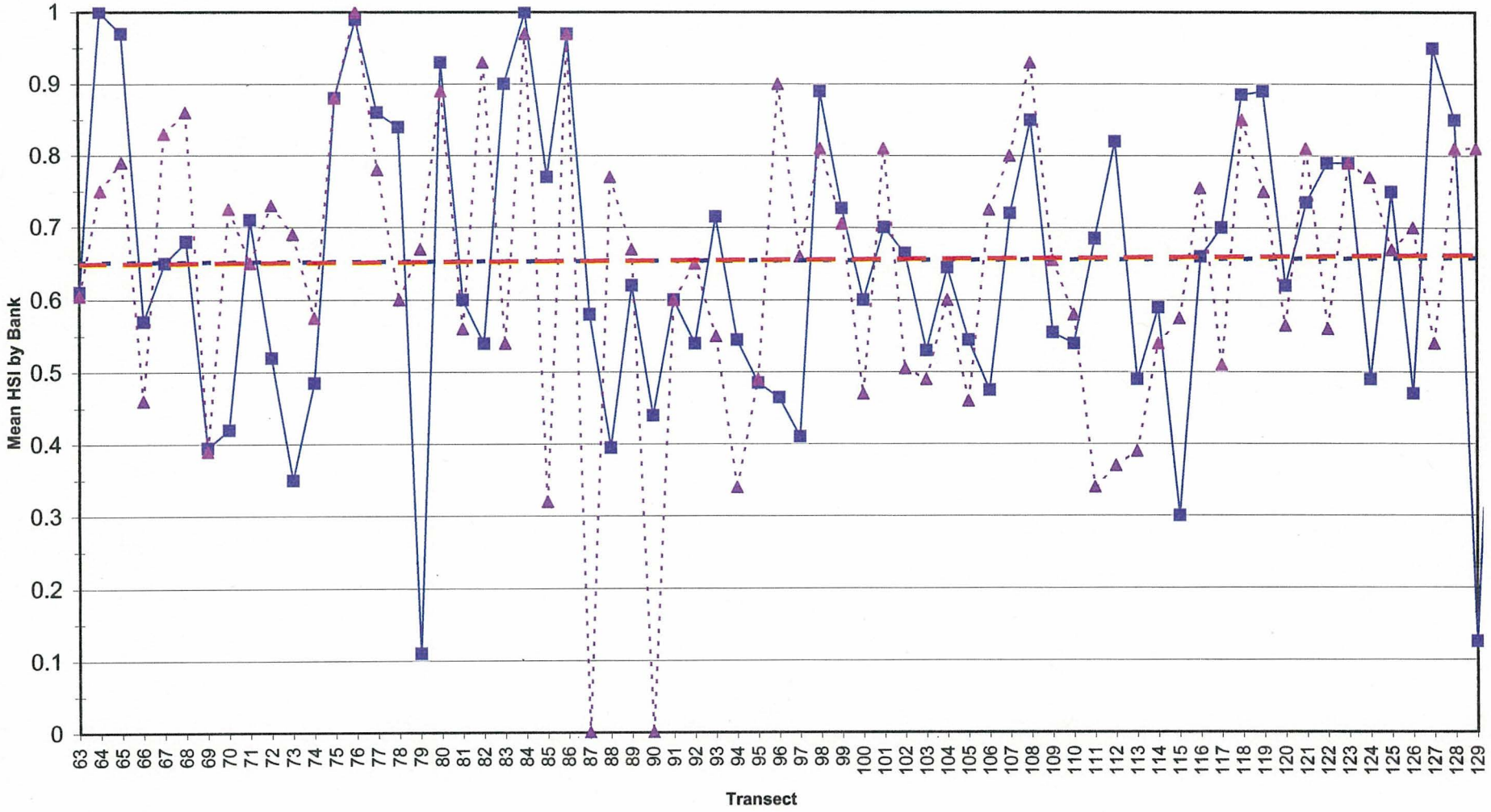
Note:
Reach 4: Transects 1 - 53
Reach 5: Transects 54 - 62

Llagas Creek Flood Control Project,
Santa Clara County

Llagas Creek - Reaches 4 & 5
Mean Habitat Suitability Indicies (HSI) by Bank

US Army Corps of Engineers
San Francisco District

PLATE 22



Legend:

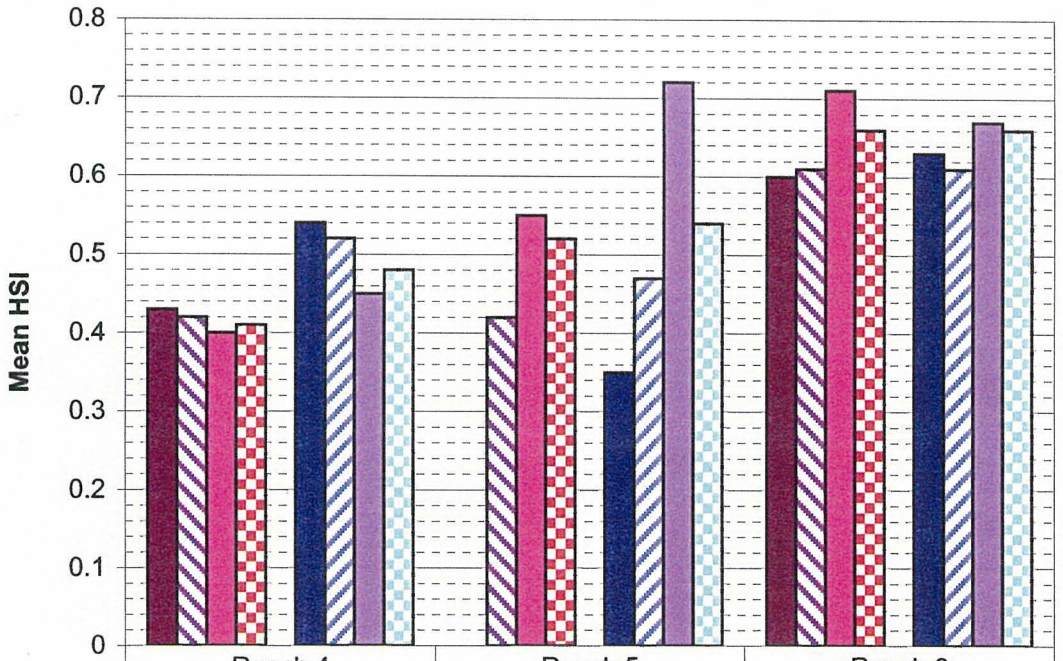
- Left Bank
- Right Bank
- Left Bank Trendline
- Right Bank Trendline

Llagas Creek Flood Control Project, Santa Clara County

Llagas Creek - Reach 6 Mean Habitat Suitability Indicies (HSI) by Bank

US Army Corps of Engineers
San Francisco District

PLATE 23



	Reach 4	Reach 5	Reach 6
Left Bank Riparian Forest	0.43	0	0.6
Left Bank Riparian Scrub-Shrub	0.42	0.42	0.61
Left Bank Upland/Herbaceous	0.4	0.55	0.71
Left Mean	0.41	0.52	0.66
	0.5		
Right Bank Riparian Forest	0.54	0.35	0.63
Right Bank RSS	0.52	0.47	0.61
Right Bank Upland/Herbaceous	0.45	0.72	0.67
Right Mean	0.48	0.54	0.66

Llagas Creek,
Santa Clara County

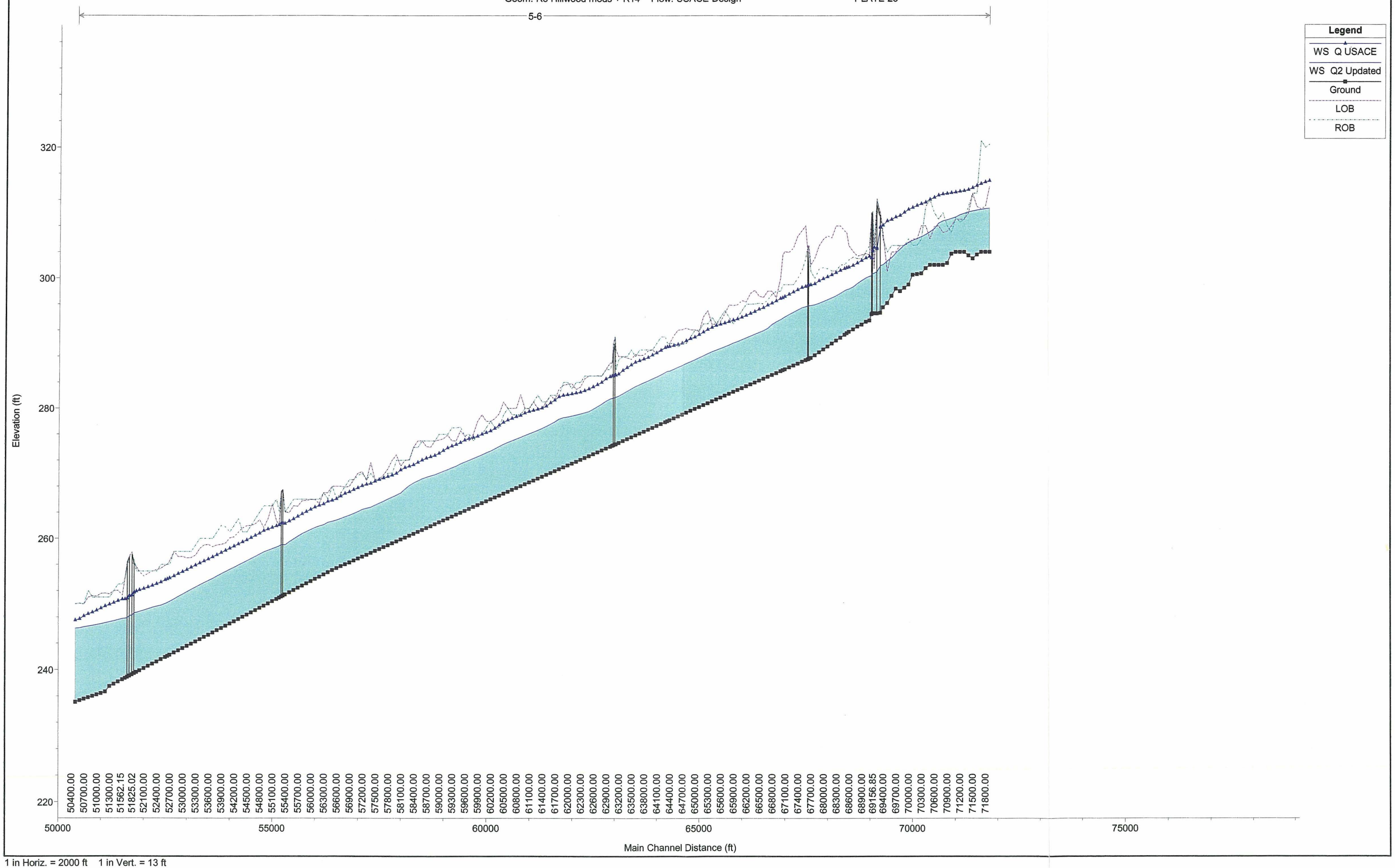
Llagas Creek, Mean HSI by Bank Summary

US Army Corps of Engineers
San Francisco District

PLATE 24

LLagas Preliminary Design Plan: preliminary design

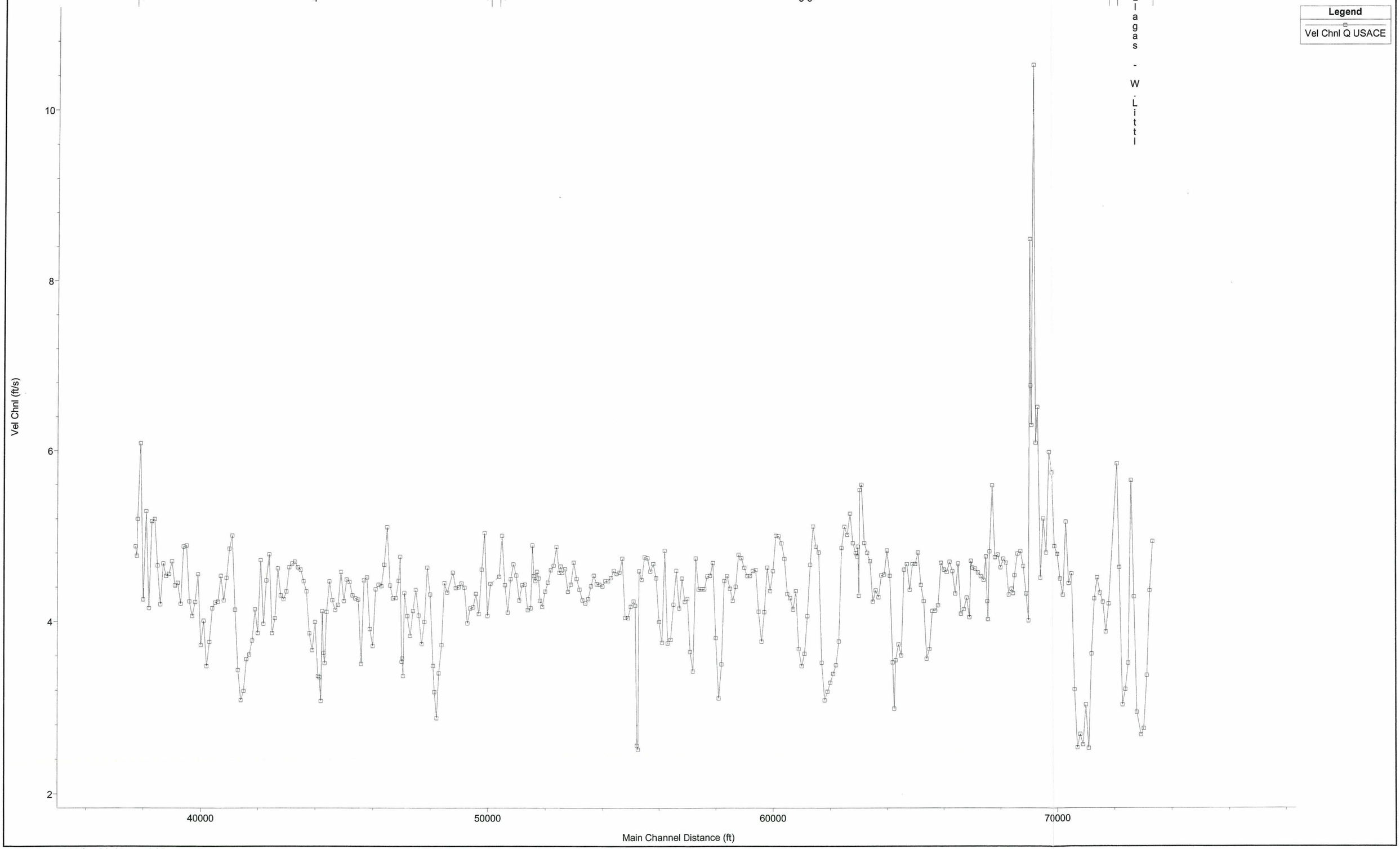
Geom: R8 Hillwood mods + R14 Flow: USACE Design PLATE 25



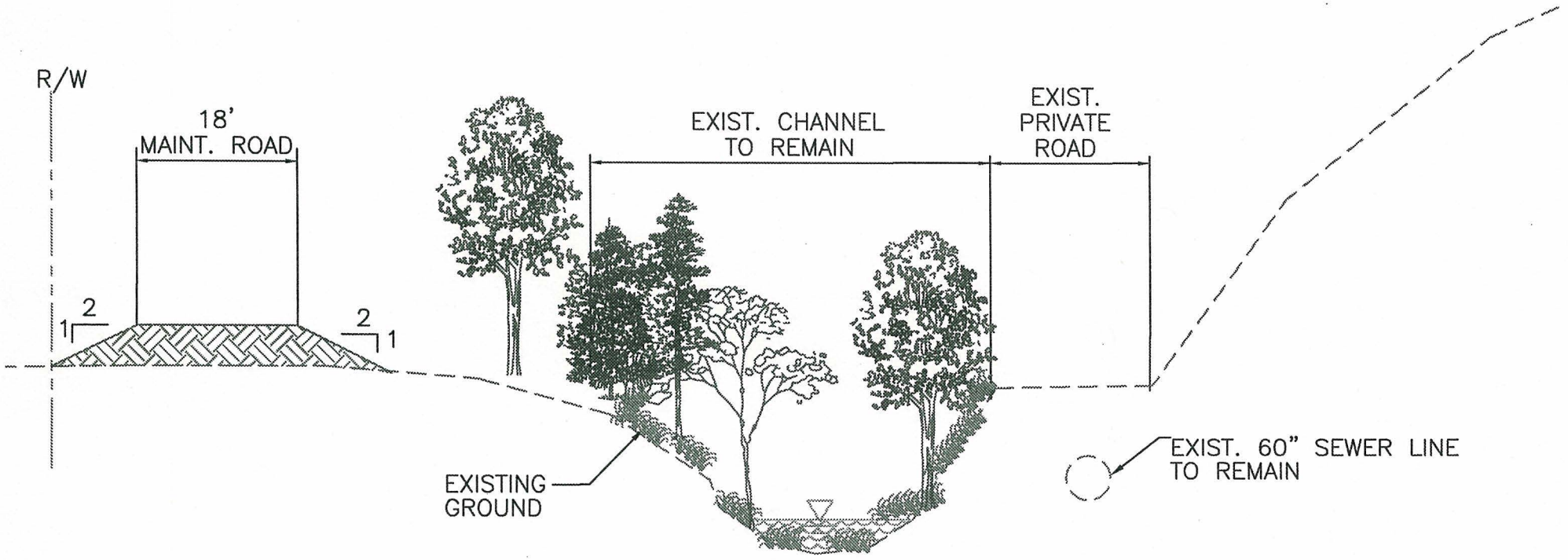
1 in Horiz. = 2000 ft 1 in Vert. = 13 ft

LLagas Preliminary Design Plan: preliminary design

Geom: R8 Hillwood mods 2 Flow: USACE Design PLATE 26



1 in Horiz. = 3000 ft 1 in Vert. = 1 ft/s



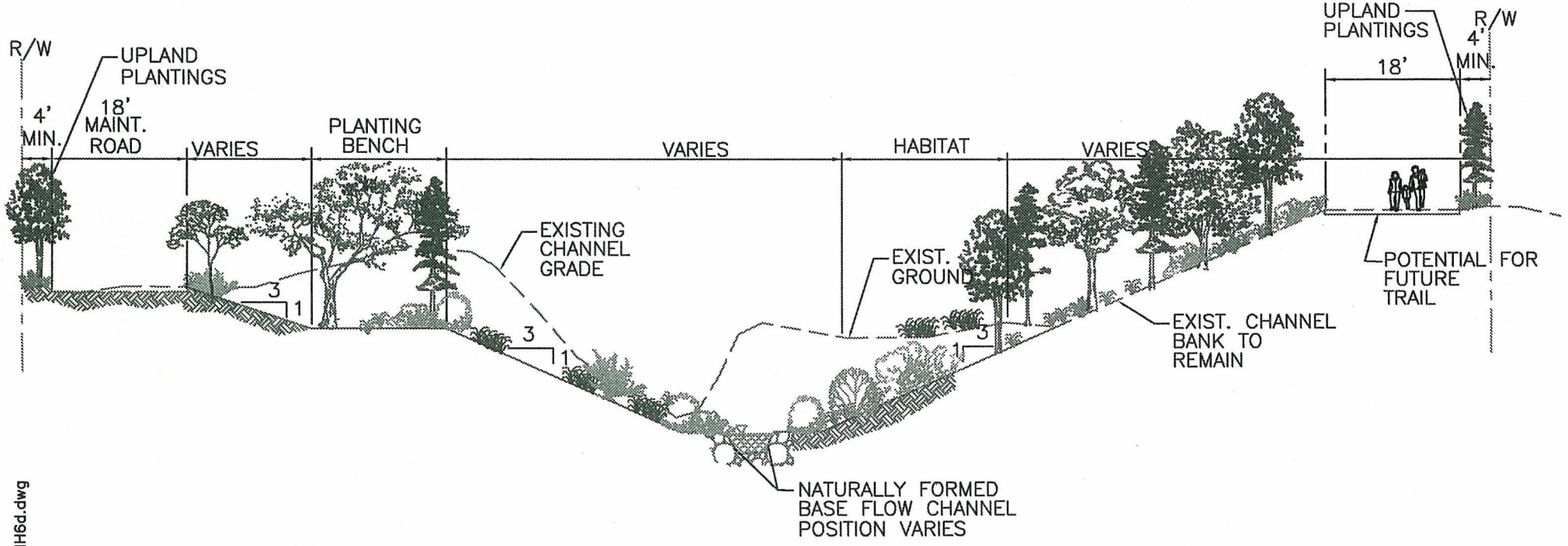
TYPICAL SECTION

LLAGAS CREEK REACH 6a
BETWEEN MONTERY ROAD AND WEST LITTLE
LLAGAS CREEK DIVERSION CHANNEL
STATION 702+00
SETBACK LEVEES
(LOOKING DOWNSTREAM)
NTS

2002 PLAN

PLATE 27

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH6e.dwg



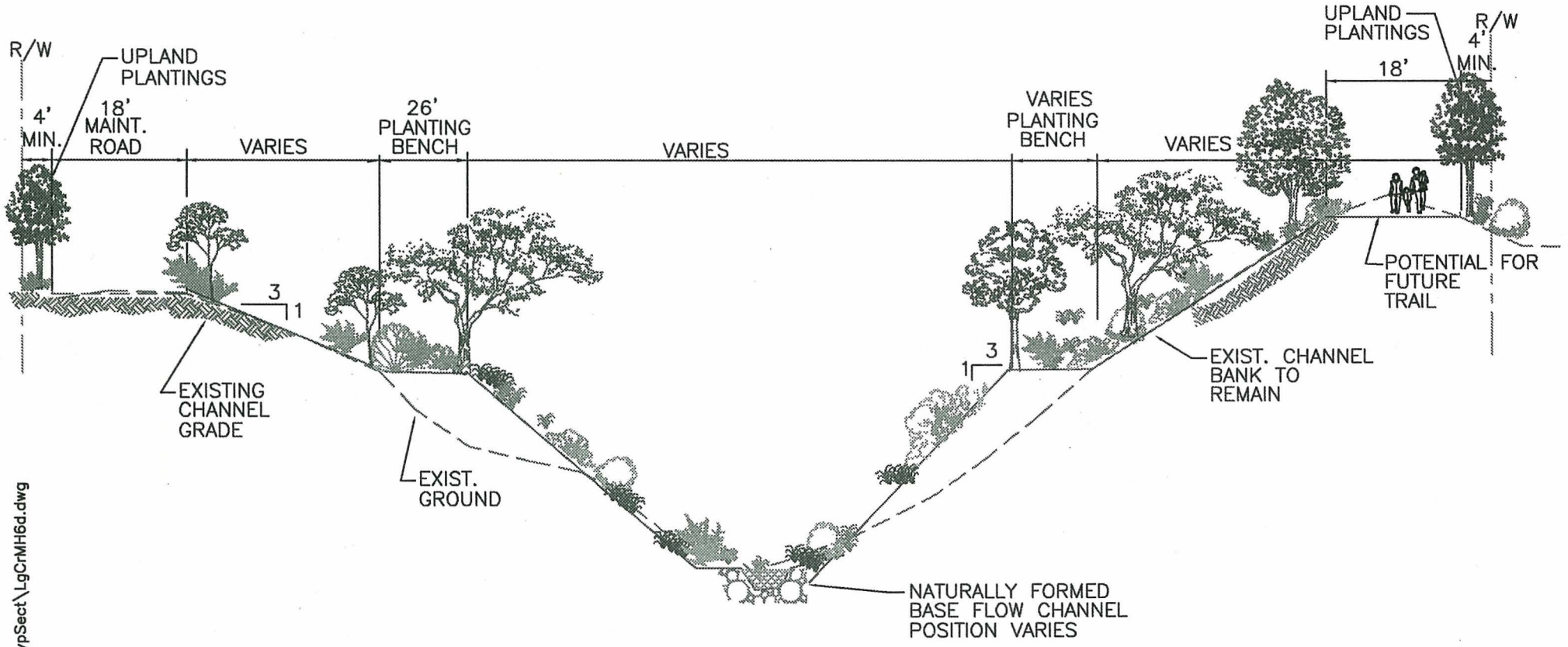
TYPICAL SECTION

LLAGAS CREEK REACH 6b AND REACH 5
STATION 660+00
(LOOKING DOWNSTREAM)
NTS

2002 PLAN

PLATE 28

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH6d.dwg



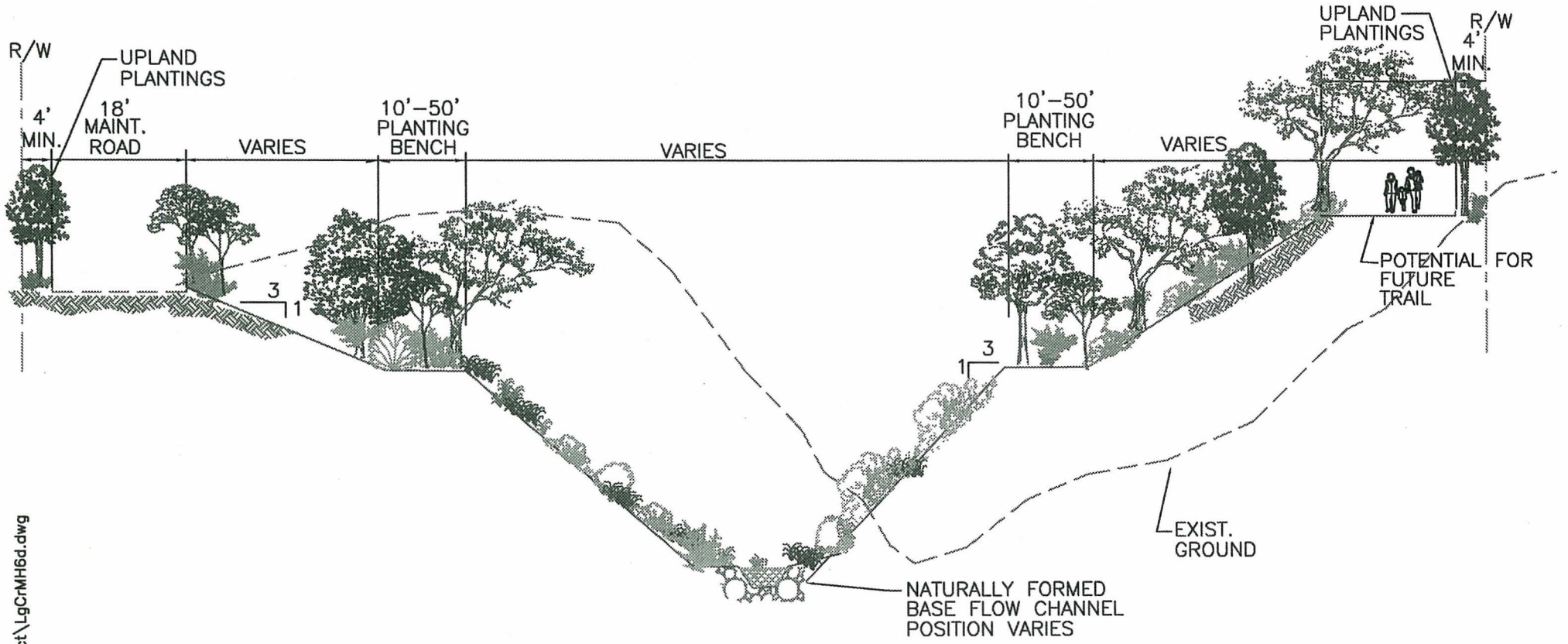
TYPICAL SECTION

LLAGAS CREEK REACH 6b
STATION 597+00 (LEFT AND RIGHT BENCHES)
(LOOKING DOWNSTREAM)
NTS

2002 PLAN

PLATE 29

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH6d.dwg



TYPICAL SECTION

LLAGAS CREEK REACH 6b

CHANNEL SHIFTED 25'–50' DOWNSTREAM OF SAN MARTIN AVE

STATION 622+00

(LOOKING DOWNSTREAM)

NTS

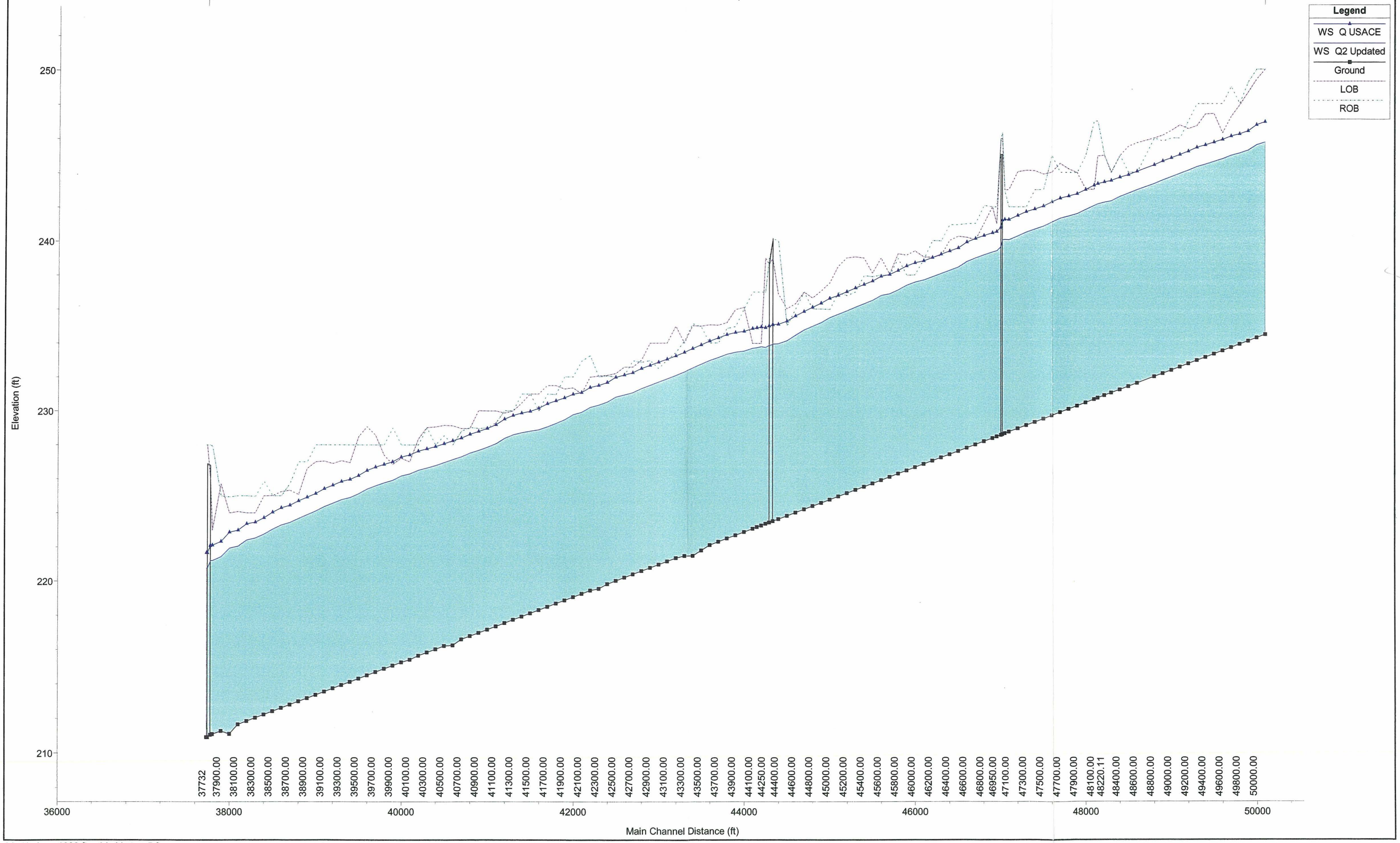
2002 PLAN

PLATE 30

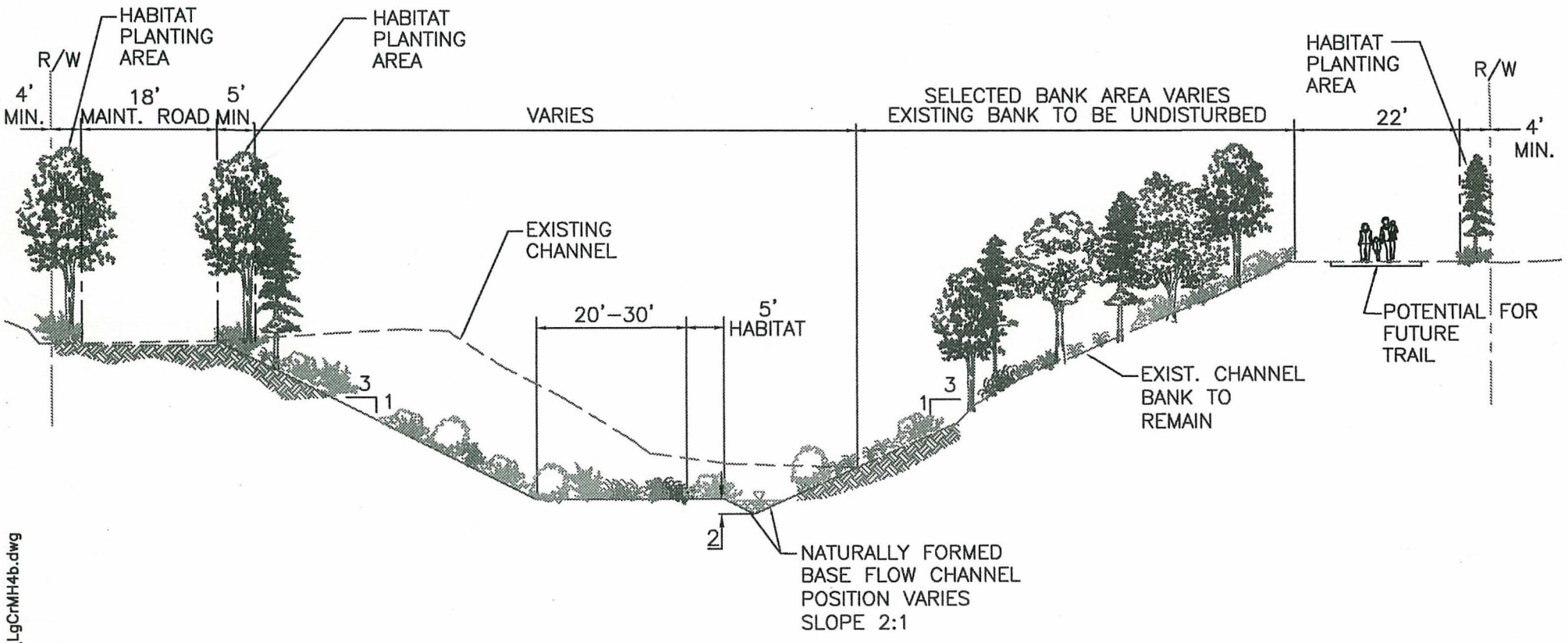
DWG FILE NAME: G:\dwgs\P\26751\TypSect\LgCrMH6d.dwg

LLagas Preliminary Design Plan: preliminary design

Geom: R8 Hillwood mods + R14 Flow: USACE Design PLATE 31



1 in Horiz. = 1000 ft 1 in Vert. = 5 ft



TYPICAL SECTION

WEST LITTLE LLAGAS CREEK REACH 4
STATION 468+00
(LOOKING DOWNSTREAM)
NTS

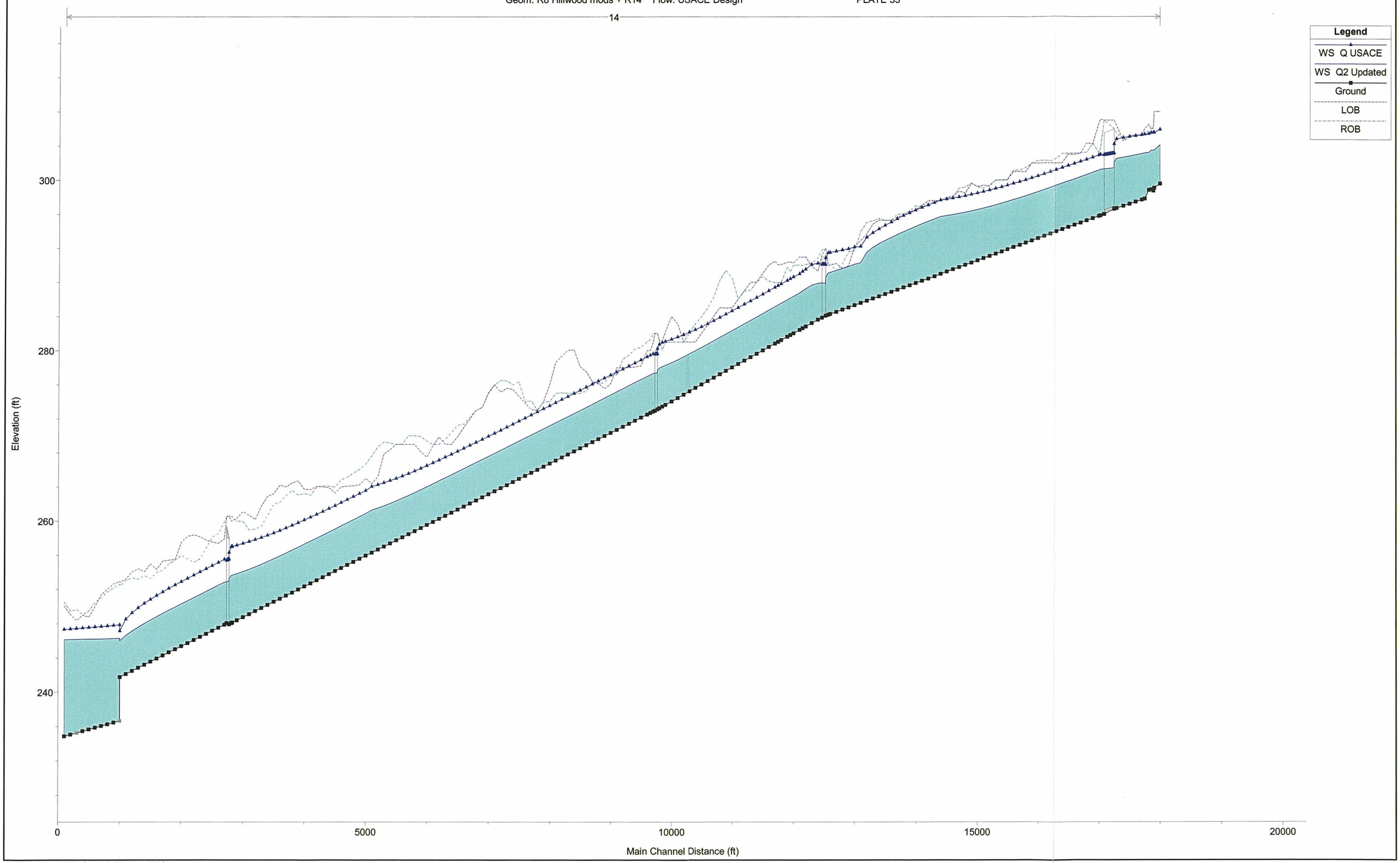
2002 PLAN

PLATE 32

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH4b.dwg

LLagas Preliminary Design Plan: preliminary design

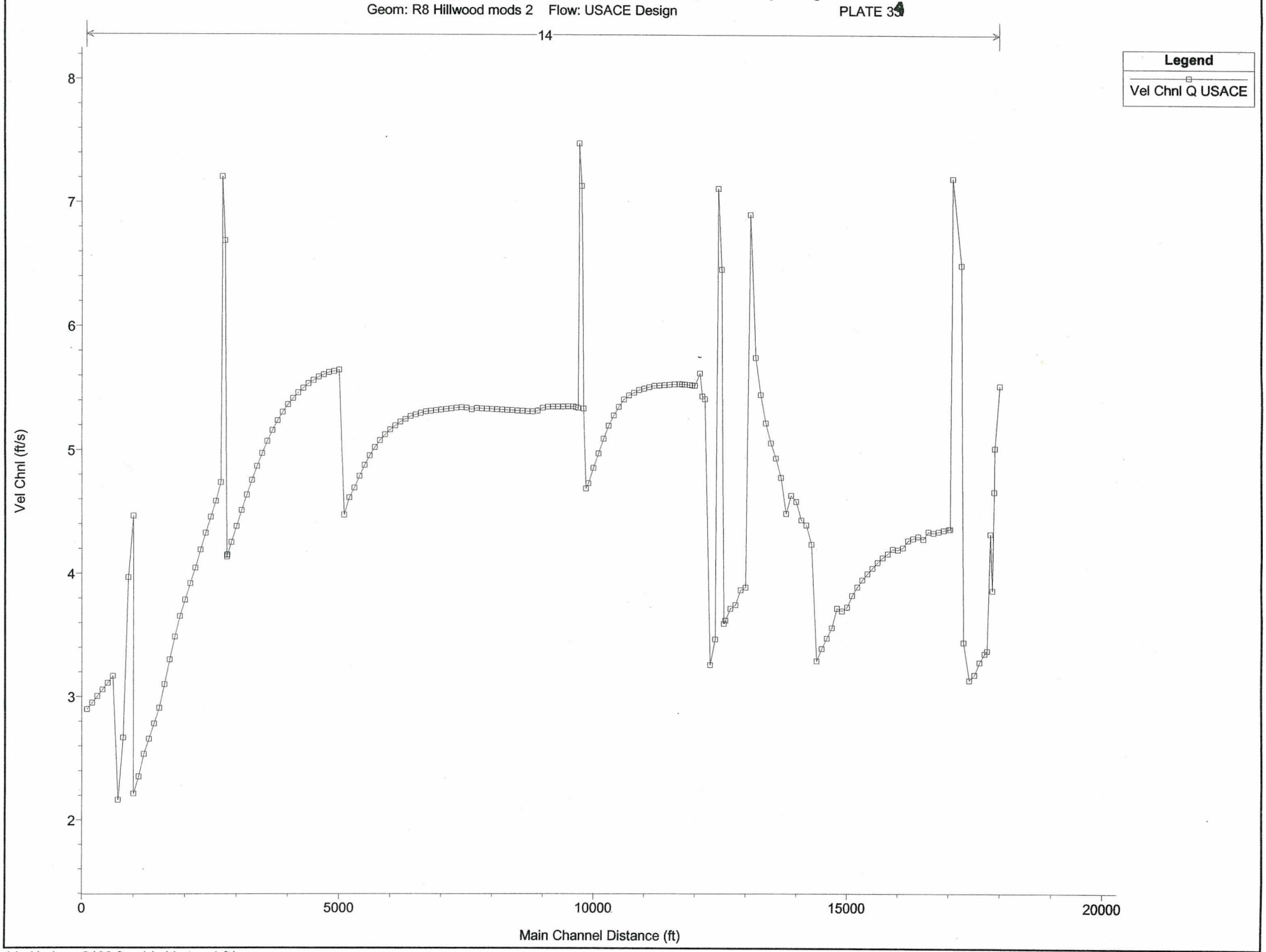
Geom: R8 Hillwood mods + R14 Flow: USACE Design PLATE 33



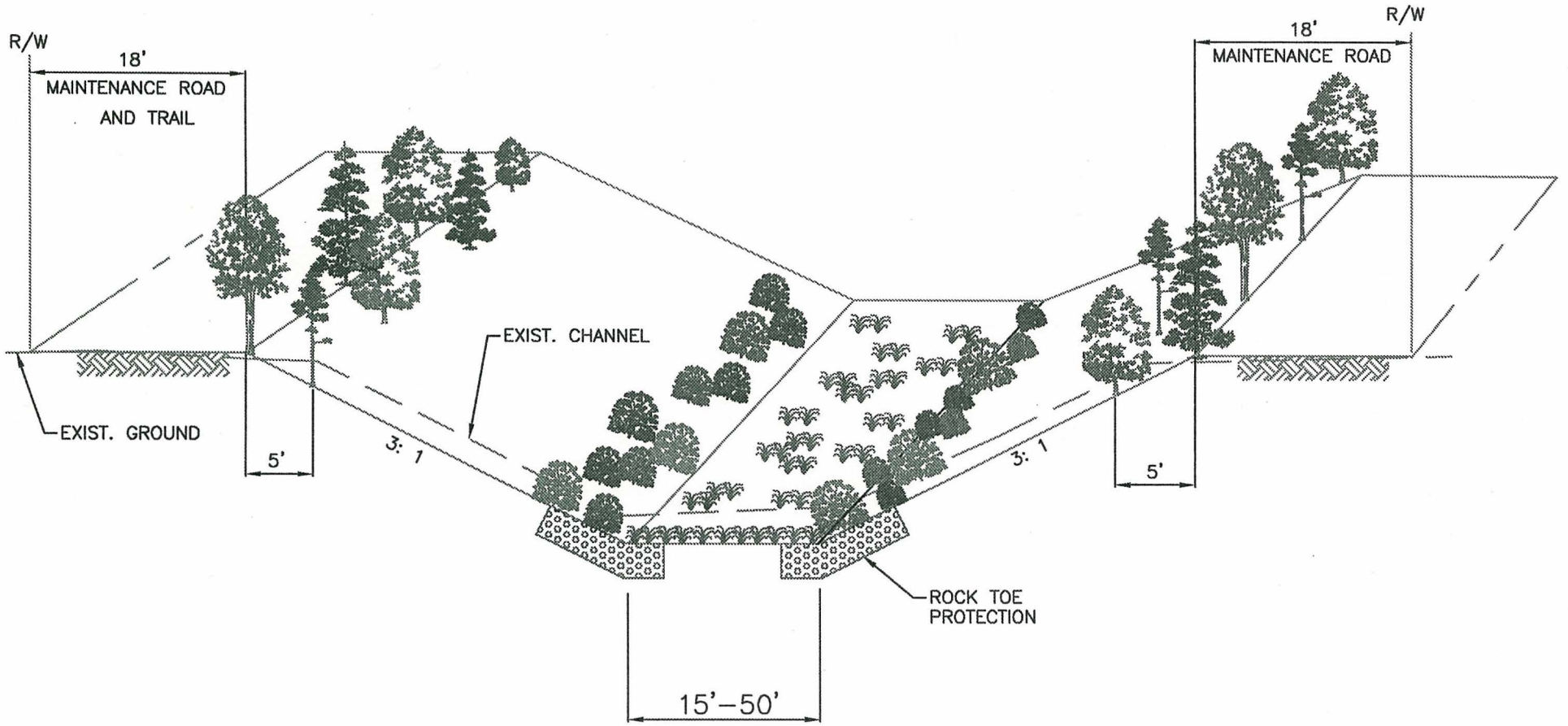
1 in Horiz. = 1400 ft 1 in Vert. = 10 ft

LLagas Preliminary Design Plan: preliminary design

Geom: R8 Hillwood mods 2 Flow: USACE Design PLATE 35



1 in Horiz. = 2400 ft 1 in Vert. = 1 ft/s

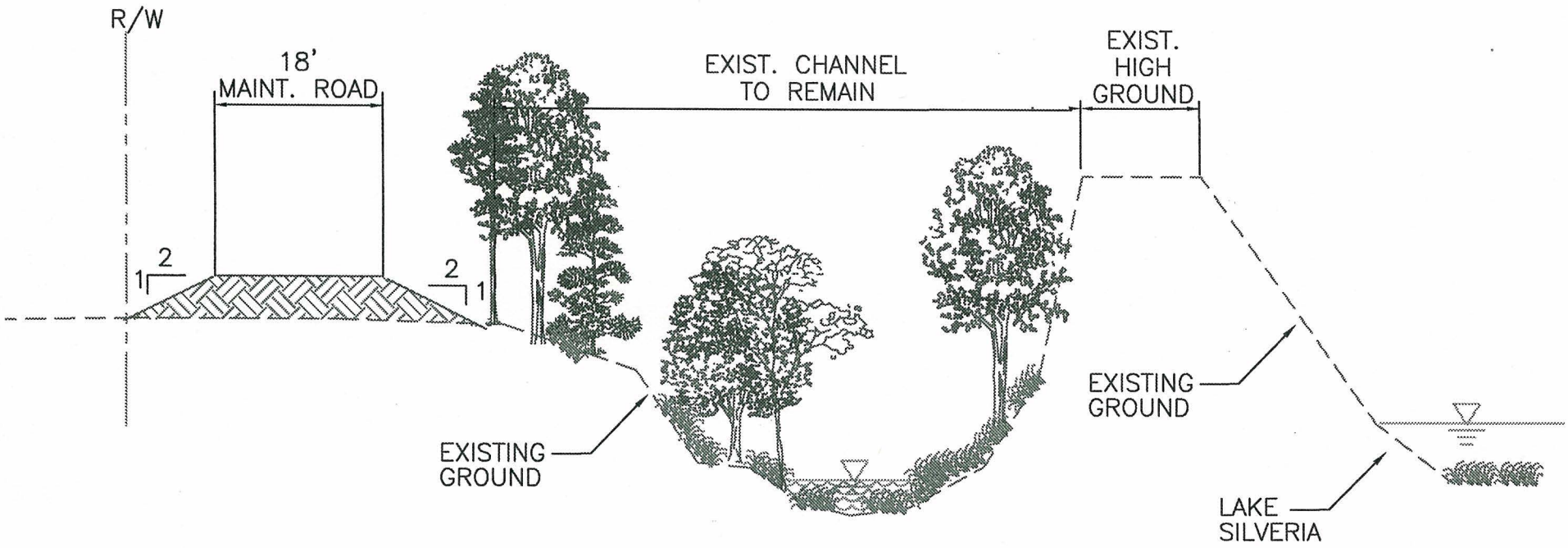


TYPICAL SECTION

LLAGAS CREEK REACH 14 (LOOKING DOWNSTREAM) NTS
BETWEEN MAIN BRANCH LLAGAS CREEK
AND 2400' UPSTREAM OF SAN MARTIN

PLATE 35

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH14.dwg



TYPICAL SECTION

LLAGAS CREEK
AROUND LAKE SILVERIA
UPSTREAM WEST LITTLE LLAGAS CK DIVERSION CHANNEL
SETBACK LEVEES
(LOOKING DOWNSTREAM)
NTS

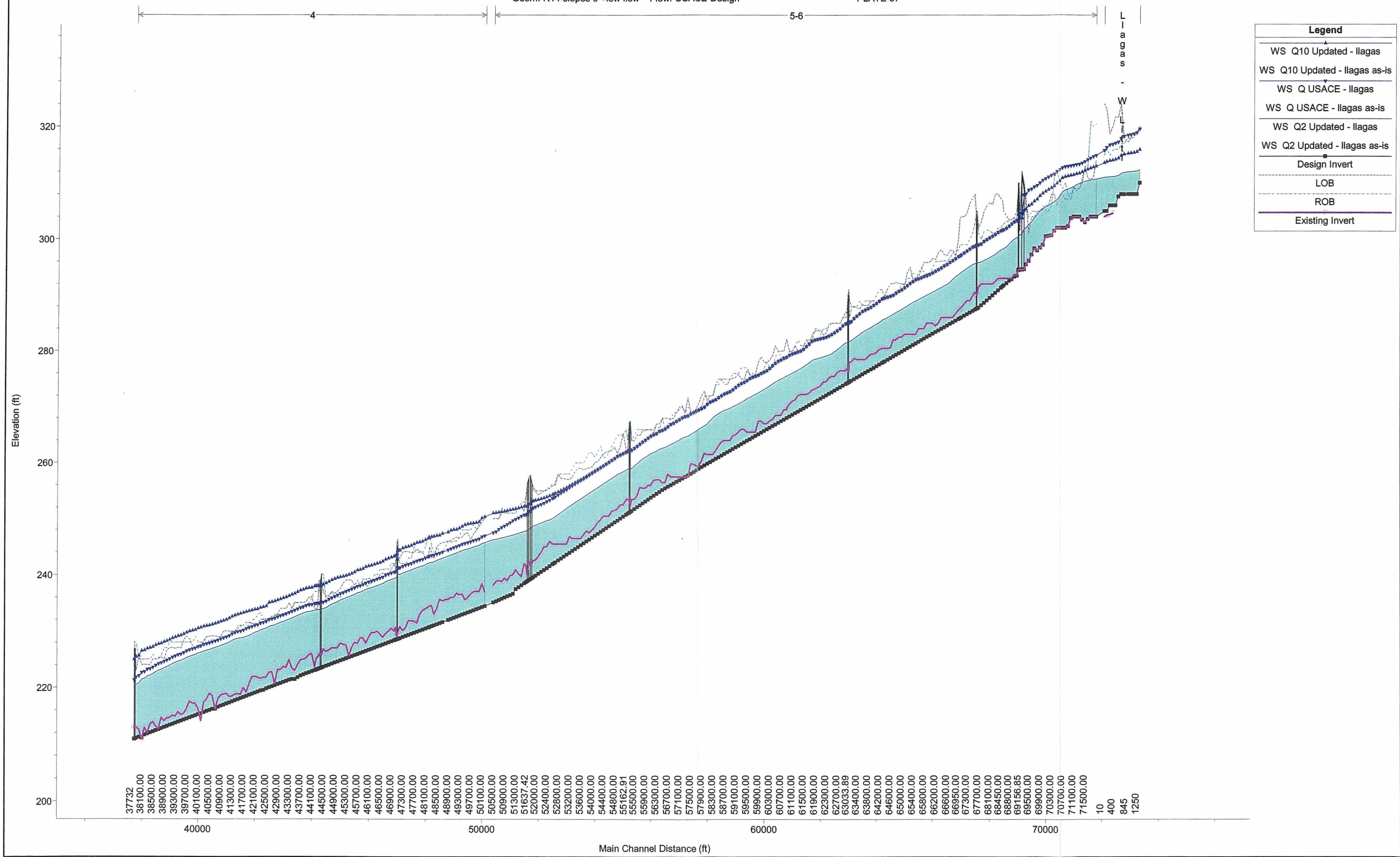
2002 PLAN

PLATE 36

DWG FILE NAME: G:\dwgs\P\267511\TypSect\LgCrMH6e.dwg

LLagas Preliminary Design Plan: 1) llagas 2) llagas as-is

Geom: R14 slopes 6 +low flow Flow: USACE Design PLATE 37



1 in Horiz. = 3000 ft 1 in Vert. = 15 ft